MEDICAL ASPECTS OF FLIGHT SAFETY

(The Unexplained Aircraft Accident)

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FOREWORD

The increasing performances of modern aircraft give to flight safety a more and more important role in the responsibilities of the authorities concerned. In spite of the improvements in aeronautical techniques, the human element is still an essential feature in the operation of an aircraft and the origin of aircraft accidents.

Therefore, the AGARD Aeromedical Panel devoted two symposia (Oslo-Copenhagen, 1956, and Paris, 1957) to "The Medical Aspects of Flight Safety". This AGARDograph gathers a selection of reports which are within the limits imposed by the terms of reference of this organization.

The following sketch plan has been adopted

Chapter I—Flight Safety and Aircraft Accidents—Generalities

Chapter II—Unexplained Aircraft Accidents

Chapter III—Use of Pathology in Crash Injuries

Chapter IV—In Flight Protection

Chapter V—Some Special Problems

Such a plan corresponds to a need of clarification and methodology Chapter I is the essential part of this work; it discusses the physiological problems associated with high-altitude flight, the general or special, physiological and psychic factors, considered as a cause of most aircraft accidents

Chapter II (The Unexplained Aircraft Accident) is composed of only three reports. The authors have limited their studies to this particular problem. They furnish statistical data and stories of unexplained aircraft accidents which awaken an obvious interest. But it is clear that a complete medical study of this category of accidents would have included a series of hypotheses, extrapolated from the positive data which were discussed in Chapter I, and which do not need a new emphasis.

Chapter III, devoted to Pathology, contains original and as yet little-known views on the importance of this discipline in the evaluation of the causes of accidents. These first results open a vista of the fruitful future, when it will have the development it deserves, in the procedure of inquiries, in case of aircraft accidents.

Chapter IV summarizes the present achievements in flight protection and proposes solutions for the future.

Chapter V is an appendix. It collects papers only indirectly related to the main subject

The Aeromedical Panel keeps in mind that its mission in NATO is that of an advisory group and not of an academic society. The purely scientific papers and the theoretical discussions, although they may present a major interest, must give way to actual cases and practical conclusions—to the essential conditions of efficiency. It must also be noted that the opinions expressed by the authors are solely their own responsibility and do not necessarily express those of the Aeromedical Panel. The latter ones are

officially expressed in the recommendations and proposals addressed to the proper authorities.

An abstract of all papers is translated into English and French.

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AVANT PROPOS

LES performances croissantes des avions modernes confèrent à la sécurité des vols une place de plus en plus importante dans les préoccupations des autorités responsables. En dépit des perfectionnements de la technique aéronautique le facteur humain continue à jouer, dans la conduite de l'avion et dans la genèse des accidents aériens, un rôle primordial.

C'est pourquoi le Groupe Aéromedical de l'AGARD a consacré deux symposiums (Oslo–Copenhague, 1956, et Paris, 1957) aux "Aspects Médicaux de la Sécurité Aérienne" La présente AGARDographie rassemble un choix de rapports qui se situent dans le cadre fixé à cette organisation par son statut

Le plan suivant a été adopté

Chapitre I—Sécurité Aérienne et Accidents Aériens en Général.
Chapitre II—Accidents Aériens Inexpliqués
Chapitre III—Rôle de l'Anatomo-pathologie dans l'étude des Accidents
Chapitre IV—Protection en Vol
Chapitre V—Problêmes Particuliers

Un tel plan est schématique et méthodologique. Le Chapitre I constitue l'essentiel de ce travail, il expose les problèmes physiologiques liés au vol à haute altitude, les facteurs généraux ou particuliers, physiologiques et [illegible]

[illegible] lier. Ils apportent des données statistiques et des relations d'accidents inexpliqués qui présentent pour le lecteur un intérêt indiscutable. Mais il est evident que l'étude médicale complète de cette catégorie d'accidents eut comporté une série d'hypothèses tirées par extrapolation des notions positives déjà exposées dans le Chapitre I, et qu'il était inutile d'y insister davantage.

Le Chapitre III, consacré à l'anatomo-pathologie, comporte des notions originales et encore peu connues sur le rôle de cette discipline dans la détermination des causes d'accidents. Ces premières constatations font [illegible] loppe-

[illegible] le et propose des solutions pour l'avenir.

Le Chapitre V n'est qu'une annexe. Il rassemble des rapports qui n'ont qu'une relation indirecte avec le sujet principal. Le Groupe Aéromédical n'oublie pas que sa mission au sein de l'OTAN est celle d'un groupe consultatif et non d'une société savante au sens habituel du mot. Quel qu'en soit l'intérêt, les exposés purement scientifiques et les discussions théoriques doivent céder le pas aux observations concrètes et aux conclusions pratiques, condition essentielle d'efficacité Il est également à remarquer que les opinions exprimées par les auteurs n'engagent que leur propre responsabilité et ne représentent pas nécessairement celles du Groupe Aéromédical, celles-ci s'expriment officiellement dans les recommandations et des propositions adressées à des Autorités Supérieures.

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I. FLIGHT SAFETY AND AIRCRAFT ACCIDENTS—GENERALITIES

brutale, l'abaissement considérable de la température, le souffle d'air (dans les avions de gros volume) et enfin la diminution rapide de la pression. Les effets de ce dernier facteur ont été particuliérement étudiés surtout aux U.S.A. et en France où VIOLETTE y a consacré, ces temps derniers, toute une série de recherches*. Grâce à l'établissement de lois de décompression pulmonaire, cet auteur a pu préciser les conditions dangereuses au cours des décompressions explosives et, partant, les normes de construction exigibles d'une cabine pressurisée pour mettre les occupants à l'abri d'accidents physiopathologiques.

Pour que les décompressions ne créent aucune surpression à l'intérieur des poumons, il suffit que le plus grand coefficient de fuite de la cabine soit inférieur au coefficient glottique le plus bas, c'est-à-dire à 1/100 m^2/m^3, ce qui, avec un facteur de sécurité de 100 pour cent, donne un coefficient de fuite maximum de 1/200 m^2/m^3. Ce coefficient met à l'abri des risques de

pression le rapport.

pression cabine/pression extérieure.

C'est ainsi que pour un avion dont le volume de la cabine est de 80 m^3, prévu pour voler à 12,000 m (soit une pression extérieure de 144·6 mm Hg) avec une pression à l'intérieur de la cabine de 674 mm Hg équivalente à une altitude de 1000 m, la rapport de pression est de 4·66, donc supérieur à 4 L'ouverture accidentelle de la cabine (éclatement d'un hublot par exemple) ne devra donc pas dépasser $80 \times 1/200 = 0{\cdot}4$ m^2. Si ce même *avion était prévu pour voler à 9000 m (soit une pression extérieure de 230* mm Hg) avec une même pression cabine équivalente à 1000 m, le rapport de pression qui est alors de 2 9, permettrait une ouverture de 1 6 m^2 sans

Ces conditions ne sont malheureusement pas réalisables sur les avions de guerre dont la cabine est de petite dimension, comme les avions de chasse par exemple. Dans ce cas, le coefficient de fuite en cas de rupture de canopy est de l'ordre de 1/2 m^2/m^3. L'expérience montre que dans ce cas, si l'on

maintenir dans la cabine une pression proche de celle qui règne au sol.

Deux facteurs jouent alors dans le calcul de la pressurisation, l'hypoxie

altitude maximum de 10,500 m. En ce qui concerne l'hypoxie seulement, on peut donc en gardant le rapport pc/pa à sa valeur limite de 2 3 calculer la

* *La Médecine Aeronautique*, 9, 223, 1954 Thèse pour le Doctorat en Sciences Paris 1955.

Tableau I

	km	*Températures*	*Caractéristiques Chimiques*	*Pression* mm Hg	
Espace interplanétaire					
	1400				
			H^+c		
	1200				
Exosphere	1000				Aurores boreales Les plus élevées
	800				
			N_2 MC H HC		
	600				
		—Wac corporal +V2			
	400				
		— Vicking			Couche F 1 Couche F 0
	200				
		—V2	$N_2 \rightarrow N+N$		Couche E
	180				
Ionosphere					
	150				
	140				
		Temperatures elevées — véronique	N_2O		
	130				
		—Aerobée Temperature froide			Meteorites
	100				
			$O_2 \rightarrow O+O$	0 1	Nuages phosphorescents
	80				
		—Wac corporal		0 2	Aurores boreales Les plus basses
	60				
Stratosphère		Temperature elevée	O_2N_2	2 0	
	30				
		—Skyrocket Temperatures froides	O_2	4 1	Rayonnement cosmique maximum
	20				
	12				
Troposphère					

limite supérieure de vol pour laquelle on évite le risque de décompression explosive et celui de l'hypoxie en vol normal. La pression de 10,300 m est environ de 187 mm Hg, on aura donc:

$$pa = pc/2\cdot3 = 187/2\cdot3 = 81\cdot3 \text{ mm Hg}$$

ce qui correspond à une altitude maximum de vol de 15,600 m.

En ce qui concerne l'aéroembolisme, on sait que si l'on veut voler pendant une longue période de temps sans risque d'aéroembolisme (sans dénitrogénation préalable), il ne faut pas dépasser l'altitude de 7000 m cabine environ. Il nous est facile de calculer dans ce cas également, l'altitude

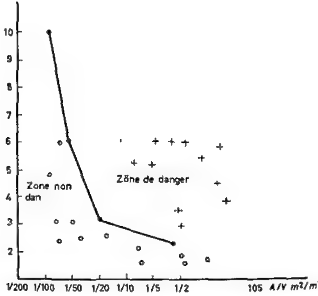

Fig 1 *Courbe expérimentale indiquant la zone dangereuse des décompressions explosives compte tenu du rapport pc/pa et du coefficient de fuite A/V.*

+ *décompressions explosives ayant entraîné des lésions*
• *décompressions explosives limites*
° *décompressions explosives inoffensives*

(*d'après* VIOLETTE)

maximum de vol pour laquelle on élimine à la fois les risques d'aéroembolisme et de décompression explosive. On a pour 7000 m cabine $pc = 308$ mm Hg, et

$$pa = pc/2\cdot3 = 308/2\cdot3 = 133\cdot9 \text{ mm Hg,}$$

ce qui correspond à une altitude de vol maximum de 12,500 m

Pour nous résumer, si l'on veut éviter les risques de décompression explosive da[illegible] maximum de vol sera de [illegible] ans ces deux cas, le risq[illegible] l se pose le problème de la protection contre l'anoxémie qui suit immédiatement la

perte de la pressurisation cabine Elle est facilement résolue à 12,500 m par l'inhalation d'oxygène pur à la pression ambiante ou mieux sous une faible surpression, à 15,600 m nous nous trouvons en dehors des limites d'utilisation de l'inhalation d'oxygène en surpression telle qu'elle est réalisée par des régulateurs comme le Bronzavia 316 et le D_2.

Nous voyons donc qu'au dessus de 15,000 m, dans le cas d'un chasseur, nous nous trouvons devant des problèmes nouveaux qui demandent des solutions particulières an admettant que le pilote a subi la dénitrogénation avant le vol, deux graves problèmes se posent·

—protection contre la décompression explosive,

—protection contre l'exposition aux très basses pressions atmosphériques qui suit immédiatement la perte de pressurisation.

Protection contre la décompression explosive

Nous venons de voir que pour un chasseur dont la cabine est construite de façon classique nous avions un coefficient de fuite (surface du canopy/volume de la cabine) de l'ordre de 1/2 et qu'en raison de ce coefficient, nous étions obligés de conserver une différentielle cabine telle que $pc/pa \leqslant 2\ 3$.

Si l'on désire augmenter le plafond de l'appareil tout en conservant une altitude cabine suffisamment basse pour ne pas dépasser le plafond d'utilisation des inhalateurs, nous pouvons jouer sur la surface de l'ouverture accidentelle possible. Prenons, par exemble, en nous plaçant dans des conditions extrêmes, celles d'un vol à une altitude de 40,000 m. La pression extérieure est alors de 2 mm Hg, et la pression cabine, par définition, de 187 mm Hg. Le rapport pc/pa est alors de 187/2. Pour éviter le risque immédiat de la décompression, il faut donc une ouverture maximum $A \leqslant V \times 1/200$ m^2, soit, en admettant un volume de 1 20 m^3 pour la cabine, $A \leqslant 1\ 20 \times 1/200$, ce qui donne $A \leqslant 60$ cm^2. Ce simple calcul montre qu'il est pratiquement impossible d'éliminer à très haute altitude le danger de décompression explosive en jouant uniquement sur la surface maximum des hublots, à moins de supprimer le canopy actuel et de construire un canopy à toute épreuve. De toute façon, le risque de décompression explosive sera inévitable en temps de guerre, au moment de l'impact d'un projectile dans la cabine Comment, dans de telles conditions, assurer la sécurité du pilote? Seul un équipement personnel de protection peut-être envisagé.

Le scaphandre aérien est la solution la plus séduisante du point de vue physiologique. En effet, enfermé dans son scaphandre, le pilote ne subira aucune variation de pression en cas de perte brutale de la pression cabine. Autre avantage, le danger de décompression explosive étant éliminé, il sera alors possible de maintenir la pression cabine à des niveaux très élevés, et de supprimer les risques d'aéroembolisme. Ainsi serait éliminée l'obligation de la dénitrogénation si génante du point de vue opérationnel du fait de l'immobilisation du personnel à terre avant la mission. Libéré de la crainte de la décompression explosive, de l'aéroembolisme et de l'anoxémie, placé dans des conditions de pression confortables, le pilote gardera toute son efficience. On peut encore ajouter que la scaphandre pourrait encore résoudre le problème de protection contre le vent, le froid, la chaleur et même l'immersion dans les mers froides.

Malheureusement, la construction d'un scaphandre se heurte à de nombreux obstacles qui n'ont pas encore été surmontés de façon satisfaisante. Ces obstacles étant principalement: la réduction de la mobilité des différents segments du corps, le poids, l'encombrement et la difficulté de ventilation intérieure. En l'absence d'un scaphandre entièrement satisfaisant, la question de la protection contre la perte de pressurisation par un équipement personnel reste posée; elle est a l'étude actuellement, dans différents pays et spécialement en France.

Cette protection

—contre l'anoxémie au-dessus de 15,000 m;

—contre l'ébullition des liquides organiques à partir de 20,000 m environ (et non pas de 19,000 m comme on l'a dit souvent, car il faut tenir compte des pressions internes des liquides organiques différents de l'eau),

a reçu une solution provisoire qui est la combinaison pressurisée. Nous n'insisterons pas sur le principe et le fonctionnement de cet équipement, à propos duquel une conférence sera consacrée ultérieurement. Disons seulement que son fonctionnement est sûr et la protection efficace jusqu'à une altitude de l'ordre de 30 à 35,000 m.

Nous verrons un peu plus loin la protection contre le froid qui suit immédiatement également la perte de la pressurisation cabine.

Pour terminer cette brève étude des problèmes physiologiques posés par la baisse de la pression barométrique, signalons que les méthodes de pressurisation employées actuellement deviendront dangereuses en haute altitude Il est en effet impossible d'obtenir des compresseurs légers et peu encombrants susceptibles de ramener à une pression suffisante l'air dans la cabine

D'autre part, la compression de l'air extérieur fortement ionisé à cette altitude, amènerait des concentrations toxiques d'ozone dans la cabine. Dans ces conditions, à partir d'une altitude que l'on peut fixer aux alentours de 20,000 m, les avions devront être obligatoirement munis d'une cabine étanche. Cette solution posera elle-même à son tour d'autres problèmes physiologiques ou mécaniques, en particulier si les sujets ne sont pas munis de vêtements spéciaux, l'élimination de la vapeur d'eau et du gaz carbonique produits par les occupants de l'avion, ainsi que la climatisation de la cabine

Pour nous résumer, nous pouvons dire que la baisse considérable de pression atmosphérique au-dessus de 15,000 m pose une série de problèmes en ce qui concerne la sécurité au cours du vol; la combinaison pressurisée est une solution partielle et transitoire, le scaphandre et la cabine étanche seront vraisemblablement la seule réponse pleinement valable à ces problèmes.

Problèmes Posés par les Radiations en Altitude

(I) *Rayonnement lumineux*

A mesure que décroit la pression barométrique, la protection normale qu'apporte l'atmosphère vis-à-vis du spectre lumineux émis par le soleil diminue et l'ambiance lumineuse entourant l'avion change considérablement.

Le rayonnement émis par le soleil subit en effet un certain nombre de transformations au cours de sa traversée de l'atmosphère. Les nombreuses molécules et particules qui composent l'atmosphère terrestre sont à l'origine d'un certain nombre de phénomènes : absorption, réfraction, réflexion, diffraction et dispersion qui ont pour résultat de déterminer l'intensité de la lumière nous parvenant au sol et la distribution spectrale.

La partie visible du spectre est atténuée par l'ozone, surtout dans sa zone orange, et d'une manière plus faible par la vapeur d'eau et l'oxygène.

Les infra-rouges sont absorbés en grande quantité par la vapeur d'eau, le protoxyde d'azote et le gaz carbonique

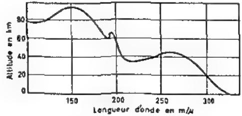

Fig 2 *Absorption des U V par l'atmosphère en fonction de l'altitude* (*Naval Research Laboratory*)

Les ultra-violets subissent également une absorption très importante par l'ozone et l'oxygène.

L'absorption des radiations infra-rouges et ultra-violettes est particulièrement importante à considérer. Tandis que la partie visible ne subit dans les couches basses de l'atmosphère, qu'une absorption de 1 pour cent, les infra-rouges sont absorbés dans la proportion de 25 pour cent, et en particulier

la bande des 7 7μ.

187 et 200 mμ.

Au total, 25 pour cent environ des ultra-violets sont absorbés par l'ozone. Un fait intéressant à noter est que la bande des 297 mμ, qui est la plus dangereuse, surtout pour les yeux, correspond avec la zone d'absorption maximum de l'ozone, la bande des 250 mμ pour laquelle la peau est également très sensible est aussi fortement absorbée.

On voit donc toute l'importance que devra avoir la protection du pilote et surtout de ses yeux contra ces radiations dangereuses aux grandes altitudes. Cette protection pourra être assurée par des écrans qui devront jouer le même rôle absorbant que l'atmosphère. La mise au point de ces écrans est du reste difficile, surtout en ce qui concerne l'absorption des infra-rouges.

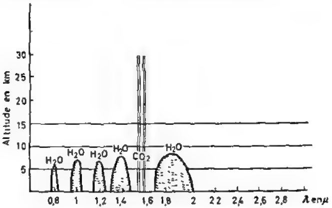

Fig 3 *Absorption des I R. en fonction de l'altitude* (J. Colin).

Mais comme nous allons le voir, la disparition de la protection apportée par l'ozone et la vapeur d'eau vis-à-vis des radiations ultra-violettes et infra-rouges n'est pas le seul phénomène d'importance pour la vision de l'aviateur. Il faut encore tenir compte de la diminution progressive de la luminosité du ciel, de la disparition de la diffusion de la lumière par les molécules de l'air et de l'influence de l'albedo de la terre

L'albedo ou degré de blancheur d'un objet est fonction de la fraction de lumiére qui est réfléchie et renvoyée dans l'espace par ce corps. Ainsi que l'a observé Danjon, la fraction de lumière renvoyée par la terre est comprise entre 0·3 et 0·5 en France. Cette fraction de lumière subit des variations saisonnières, elle varie aussi suivant les longueurs d'onde envisagées, la réflexion opérée par les nuages est la plus importante. A mesure que l'on s'élève, la luminosité du ciel diminue, c'est donc le champ visuel inférieur du pilote qui devient le plus lumineux.

La luminosité du ciel est en effet due à la diffusion de la lumière solaire par les particules de l'atmosphère Dans le cas des molécules d'air, cette diffusion est en étroite dépendance avec la longueur d'onde. Le coefficient d'atténuation de la diffusion étant inversement proportionnel à la quatrième puissance de la longueur d'onde, la quantité de lumière diffractée s'accroît rapidement à mesure que la longueur d'onde diminue. C'est pour cette raison que le ciel paraît bleu A mesure que l'on s'élève, l'épaisseur et la densité de l'atmosphère située audessus de l'observateur diminue, exactement de la même façon que la pression barométrique. C'est ainsi qu à 12,000 m la luminosité du ciel n'est plus que la cinquième de la luminosité au sol, à 30,000 m sa valeur n'est plus que le 1/30 de sa valeur à 3000 m. Il faut cependant atteindre des altitudes considérables pour que le ciel apparaisse noir, à 90,000 m, il aura la même apparence que par clair de lune au niveau de la mer, et à

150,000 m seulement, il sera complètement noir. En même temps les étoiles deviendront visibles en plein jour, ce qui est un facteur intéressant pour la navigation.

Ces conditions particulières d'illumination poseront d'importants prob- [illegible]

porteur de lunettes protectrices Il sera peut-être intéressant également de prévoir dans le cockpit des panneaux diffusant la lumière solaire pour obtenir une illumination diffuse confortable de l'habitacle.

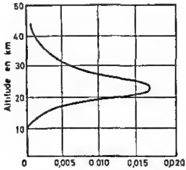

Fig 4 *Distribution théorique de l'ozone en fonction de l'altitude* (MECKE)

Enfin, il est un probleme que nous rattacherons à ce chapitre parce qu'il concerne la vision en haute altitude, c'est celui de la "myopie spaciale" Des expériences menées en particulier en Angleterre (WHITESIDE) montrent que si le champ visuel est vide, l'oeil au repos ne se met pas au point à l'infini comme on l'avait admis jusqu'ici, mais à environ 1 mètre. Ce phénomène est à rapprocher de la myopie nocturne dont le mécanisme est similaire Le pilote d'un avion volant à très haute altitude sera donc incapable de voir un autre appareil volant à une distance supérieure à 2 a 3 km du sien, même s'il en connait la direction et la distance grâce à son radar. Ce n'est qu'à partir de 2 à 3 km qu'il sera capable de le distinguer puis de voir nettement l'avion qu'il recherche.

Différentes solutions ont été préconisées pour protéger l'aviateur contre ce phénomène On pourra se reporter à ce sujet au rapport de WILLANS à la Réunion de l'AGARD de 1954.

Il sera peut-être possible en outre, de se protéger contre cette myopie spaciale par la projection sur les parois du canopy ou des hublots de repères virtuels situés à l'infini et servant de références évitant la mise au point de l'oeil à la distance de 1 m.

(II) *Rayons cosmiques*

Si en haute altitude, l'atmosphère ne protège plus contre les radiations lumineuses, il en est de même pour les radiations cosmiques.

On croyait autrefois que les rayons cosmiques consistaient seulement en noyaux d'atomes d'hydrogène, c'est-à-dire en protons. FREIER, LOFGREN, NEY, OPPENHEIMER ont montré en 1948 que les rayons cosmiques ...
prenaient ...
des r ...
des c ...
et le ...

Or ... le nombre des particules primaires cosmiques qui atteignent les couches supérieures de l'atmosphère. Par heure et par centimètre carré, on dénombre 4000 protons, 1000 particules, 20 noyaux de carbone, 1 noyau de fer (VAN ALLEN et TUTEL), BRADT et PETERS ont indiqué la répartition suivante: H/He/noyaux lourds = 79/20/1.

Environ la moitié des protons primaires pénètre dans l'atmosphère jusqu'à une altitude de 20,000 m. L'altitude minimum que puissent atteindre les noyaux lourds primaires est d'environ 18.000 m. Au-dessus de cette altitude leur nombre s'accroit de façon considérable, jusqu'à un maximum qui commence à une altitude de 36,000 m. Le peu d'atmosphère qui subsiste au-dessus de cette altitude n'a qu'un effet négligeable sur la densité et la nature des particules cosmiques qui la traversent.

Le pouvoir de pénétration dépend de la vitesse et de la masse de chaque particule. Certaines traversent l'atmosphère jusqu'à la surface de la terre, on a comparé cette traversée de l'atmosphère à celle d'une plaque de plomb de 94 cm d'épaisseur, ce qui donne une idée de leur pénétration et aussi de l'énorme dissipation d'énergie qui l'accompagne.

Lorsque les particules primaires rencontrent des molécules d'air, elles produisent des mesons, des électrons, des positons, et des rayons gamma (rayonnements secondaires et tertiaires)

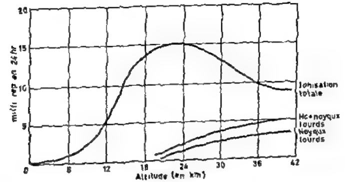

Fig 5 *Ionisation totale en milli roentgens dans des tissus vivants soumis aux radiations cosmiques (latitudes Nord)* (*d'après* J. SCHAEFER).

L'ionisation totale, pour une altitude donnée, est fonction de la latitude. BOWEN, MILLIKAN, NEHER ont montré que ce phénomène était du à

l'influence du champ magnétique terrestre qui dévie les particules des radiations cosmiques chargées électriquement, et l'intensité des rayons cosmiques augmente pour une même altitude lorsque l'on se déplace de la région équatoriale vers les pôles.

Les effets biologiques des radiations cosmiques sont principalement dus au phénomène de l'ionisation. On peut donc, dans une certaine mesure, prévoir leurs effets sur l'organisme à partir de l'étude d'autres radiations ionisantes obtenues par les rayons X, les substances radio-actives, les accélérateurs de particules, etc. Pour pouvoir comparer entre elles les différentes radiations, il a été nécessaire de mettre au point un système d'unités La première est le roentgen, unité purement physique, qu'on a adapté à la biologie sous forme du roentgen équivalent physique (rep) qui est défini comme étant la quantité de rayonnement qui, traversant 1 gramme de tissus, libere 2 012 × 10⁹ paires d'ions. Mais à égalité de dose ainsi définie l'action biologique diffère suivant la nature du rayonnement, aussi emploie-t-on le roentgen équivalent homme ou rem D'après HOUGHTON le tableau de conversion est le suivant

Rayons X, *rayons* γ	1 (rep)	1 (rem)
Rayons β	1 "	1 "
Neutrons	1 "	4 "
Particules α	1 "	10 "
Produits de fission	1 "	27 "

L'ionisation produite par les particules lourdes primaires est semble-t-il du même ordre de grandeur, sinon supérieure à celle des produits de fission. Ce sont les noyaux lourds primaires qui sont les plus nocifs, bien que leur nombre soit petit par rapport aux protons primaires.

SCHAEFER a donné, pour un homme et par jour, la dose totale de 5 7 milli rep dans les zones supérieures de l'atmosphère (c'est-à-dire à 40,000 m et au-dessus) et pour des latitudes supérieures à 55°N

Mais il faut tenir compte aussi de ce que l'on appelle le phénomène d'étoile. Les noyaux lourds possèdant une très grande énergie, peuvent, en [illegible]

2000 par cm^3 et par jour à 26,000 D'après HABER, ce phénomène ajoute 3 2 milli rep dans les couches supérieures de l'atmosphère, ce qui nous donne une dose totale pour un homme d'environ 9 milli rep par jour

Pour connaitre l'action de ces 9 milli rep sur l'organisme, il faut d'abord les convertir en rem, ce qui est possible d'après les facteurs de conversion donnés par HOUGHTON, et, en tenant compte du fait que ce facteur de conversion (rbe) n'est pas connu de façon exacte pour l'homme, on obtient ainsi une dose totale de 0 09 rem par jour pour les altitudes considérées.

On admet aux USA (U S National Comittee ou Radiation Protection) depuis 1949, qu'une dose de 0 3 rem par semaine est la dose limite supportable. Or, un pilote volant régulièrement 1000 hr par an au-dessus de 30,000 m recevrait par semaine environ 0 09 rem, soit un peu moins du tiers de la dose considérée comme sans danger.

On s'est ainsi demandé si les rayons cosmiques ne pouvaient pas avoir une action particulière sur certains tissus ou fonctions. C'est ainsi qu'ont

Heureusement la plupart des météorites rencontrés dans la zone d'altitude considérée sont d'un poids de quelques milligrammes seulement (poussière météorique). La grande majorité des météorites, c'est-à-dire ceux dont le poids est inférieur à quelques grammes ayant été vaporisée entre 80 et 90,000 m.

Ainsi qu'il ressort des calculs statistiques de GRIMINGER, *un avion d'une* surface de 90 m² et ayant un revêtement d'une épaisseur de 2 mm 5 pourrait voler pendant près de 100 ans avant d'être traversé par un météorite.

Le danger représenté par les météorites au cours du vol à très haute altitude est donc minime, il ne doit cependant pas être sous estimé et les ingénieurs de l'aéronautique devront calculer les revêtements des avions en conséquence.

Problèmes Posés par les Variations de Température

Jusqu'à ces dernières années on a envisagé les problèmes posés par les variations de température en altitude en tenant compte seulement de la température du milieu dans lequel se déplaçait l'avion. Actuellement, il faut tenir compte en outre des modifications thermiques apportées par le passage de l'avion dans le milieu.

Les problèmes de protection de l'aviateur, à ce point de vue, se posent non seulement en vol normal, mais encore en cas de déficience du conditionnement d'air de la cabine ou d'abandon de l'avion, soumettant l'aviateur à des variations de température extrêmement importantes et brutales

Les avions futurs évolueront dans un milieu de températures ambiantes très différentes Au cours d'une ascension en haute altitude, la température diminue progressivement pour se stabiliser aux environs de $-55°C$ à partir de 10,500 m en atmosphère standard. En réalité, la hauteur de la stratopause varie de l'équateur au pôle et la température de la stratosphère varie de $-40°C$ au-dessus des pôles à $-83°C$ au-dessus de l'équateur Si on s'élève

Tableau II Températures Relevées en Fusée à Haute Altitude

Altitude (*en* km)	*Température* (*en* °C)	*Altitude* (*en* km)	*Température* (*en* °C)
12	−55	60	− 3
34	−34	80	− 70
40	−14	120	− 3
48	+50	150	+ 50
54	+35	220	+180

la température augmente et vers 45,000 m on a environ $+50°C$, puis après une nouvelle couche froide ($-70°C$ à 80,000 m) la température s'accroît à nouveau de façon considérable

Pour envisager la protection il faut tenir compte non seulement de ces écarts considérables de température, mais aussi de la température qui règne au sol dans l'avion au moment du décollage. Celle-ci peut-être très élevée elle est fréquemment de $+50°$ et au-dessus dans la cabine d'un

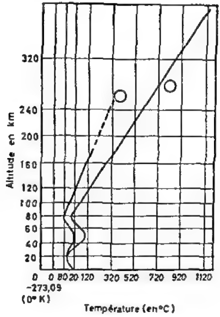

Fig. 6 1.—*Température calculée.* 2.—*Température mesurée en fusée.*

Le problème se complique encore si l'on tient compte de l'échauffement aérodynamique et de l'irradiation solaire. Le vol d'altitude, que nous considérons ici, ne peut se concevoir qu'à grande vitesse, celle-ci étant nécessaire pour obtenir sur les plans de l'appareil les pressions nécessaires à sa sustentation. L'air se raréfiant en altitude, il faut donc voler de plus en plus vite si l'on veut voler de plus en plus haut.

En rencontrant les surfaces de l'avion, l'air est brusquement décéléré et son énergie cinétique est transformée en énergie calorique. En certains points de l'avion (nez, bord d'attaque) l'air est brutalement arrêté et on peut observer, en ces points, des températures trés élevées, supérieures à 1000°C pour une vitesse de Mach 5. Aux autres points de l'avion, l'échauffement par friction aérodynamique est moindre, mais atteint environ 85 pour cent de cette valeur (Haber). Heureusement en haute altitude, l'échauffement aérodynamique de l'avion est moindre en raison de la diminution de la densité de l'air, c'est ainsi qu'un avion volant à Mach 4 à 40,000 m, ne s'échauffera pas plus qu'à Mach 1 au niveau de la mer. On pourra donc voler trés vite à haute altitude, mais il faudra toujours que cet avion traverse au décollage comme à l'atterrissage, les basses couches de l'atmosphère.

Une partie de la chaleur due aux frottements aérodynamiques est irradiée vers l'extérieur, mais une partie importante est également transmise vers l'intérieur de l'avion, amenant en définitive, un échauffement de la température de la cabine, et si on n'emploie pas de moyens spéciaux de protection, un rayonnement de la paroi vers le pilote.

L'échauffement aérodynamique n'est pas le seul à considérer, en dehors des autres sources de chaleur: moteur, compresseur, équipements divers, équipage lui-même, le rayonnement solaire à une grande importance. Les radiations lumineuses et infra-rouges pénètrent facilement dans la cabine à travers la large surface transparente que représente le cockpit. Les parois intérieures et les objets frappés par les radiations les absorbent, s'échauffent puis émettent à leur tour des rayons infra-rouges de grande longueur d'onde qui sont malheureusement arrêtées par le plexiglass.

C'est ainsi que la température cabine d'un avion volant de jour dans une région subtropicale, à une altitude de 5000 m et à la vitesse du son, atteint facilement 70°C. Cette température représente d'ailleurs la limite que l'on puisse atteindre actuellement dans une cabine, on a en effet signalé la détérioration d'instruments de bord dans de telles conditions.

Si le pilote est amené à abandonner son avion, il pourra être exposé brutalement de +70°C (température de la cabine) à −55°C (température de l'atmosphère ambiante) Si l'on veut que sa sécurité soit assurée, dans toutes les conditions, il faut donc qu'il soit protégé à la fois contre la chaleur qui règne dans son appareil et contre le froid auquel il peut se trouver brutalement exposé.

La protection contre le froid a été jusqu'à présent aisément assurée par une combinaison isolante d'une valeur de 3 clos environ. Il est évident qu'une telle combinaison serait rapidement insoutenable, même dans une cabine d'avion maintenue à une température normale de 18°C environ. Pour [illegible]

[illegible]

et sec. Avec un débit suffisant, on arrive par ce moyen à maintenir le pilote dans des conditions thermiques confortables en éliminant les calories en excédent par conduction, convection et surtout par évaporation de la sueur. Une combinaison ventilée française, caractérisée par une grande légèreté et une perte de charge minime est actuellement en expérimentation, [illegible]

des mains quoique non ventilées ne présente pas de graves problèmes, la protection de la tête est plus délicate. La ventilation de cette partie du corps est nécessaire, mais elle est difficile à assurer lorsque le pilote doit porter un casque pressurisé. D'autre part il y a lieu de considérer que la ventilation de la combinaison ne pourra être assurée en haute altitude par de l'air pris à l'extérieur étant donné l'ionisation du milieu ambiant et qu'il ne sera peut-être pas sans danger, dans certains cas, de l'alimenter en oxygène.

On peut se demander combien de temps résisterait un sujet dont le système de ventilation de la combinaison viendrait brutalement à faire défaut. De nombreux auteurs américains se sont intéressés à la résistance à la chaleur de sujets légèrement vêtus (Taylor, W. V. Blockley, J. Lyman,

N. J. McConnel, L. M. Newburg, K. Buettner). Les temps de tolérance ainsi relevés pour des sujets au repos ou n'ayant qu'une faible activité musculaire et pour un vent nul est de 70 min à 70°C, 55 min à 80°C, 40 min à 90°C, 20 min à 115°C, 5 min à 200°C.

On ne possède que peu de renseignements sur le temps de tolérance d'un sujet porteur d'une combinaison isolante. D'après Buettner la réserve de temps serait plus grande pour les températures élevées [illegible]
aclorique et à [illegible]
tuées au Labo [illegible]
contraire raccourci pour les températures de l'ordre de 70°C.

La protection contre le rayonnement calorique soit d'origine solaire, soit provenant des parois surchauffées par les frottements aérodynamiques, pourra être assurée, d'une part par une verrière absorbant le rayonnement infra-rouge, d'autre part par un casque et des vêtements réfléchissants.

Problèmes Posés par les Bruits

Si les avions ont toujours été des générateurs de bruits importants et gênants, que dire des avions modernes de hautes performances! Certains d'entre-eux, munis de réacteurs à puissants systèmes de post-combustion, produisent des bruits d'une intensité globale de plus de 150 db. Aucune machine à l'heure actuelle ne fournit des intensités bruyantes comparables. Deux rapports au dernier congrés de la branche de langue française de l'Aero-medical Association (Paris 1955)* ont fait le point des troubles physiopathologiques, engendrés par les bruits (c'est-à-dire des vibrations infra-sonores, sonores, et ultra-sonores transmises par l'air) produits par les avions actuellement en service.

Ils ont envisagé aussi les moyens classiques de protection á la ligue. Quoique à grande vitesse et à haute altitude, les bruits doivent se trouver réduits à des valeurs inférieures à celle donnée ci-dessus, il faudra envisager une protection pour l'aviateur Celle-ci ne pourra consister qu'en une combinaison spéciale qui pourra problablement être combinée avec celles que nous avons indiquées precédemment pour la protection contre la dépression et contre les variations de température, le tout ne constituant qu'un seul vêtement protecteur.

Problèmes Posés par la Diminution de la Gravité

L'absence de gravité, ou l'état de subgravité est un problème physiologique que pose le vol à haute altitude au cours de certaines évolutions de l'avion lui-même. On peut en effet prévoir qu'une proportion importante des vols effectués dans les couches supérieures de l'atmosphère seront des vols ballistiques, c'est-à-dire que le pilote coupera ses moteurs après avoir atteint une altitude et une vitesse suffisantes: il poursuivra ensuite sur sa lancée une trajectoire prévue à l'avance. Au cours de cette trajectoire, les différentes forces agissant sur l'avion (force de gravité, force centrifuge, accélération, décélération, poussée . . .) peuvent s'annuler ou avoir une omposante minime pendant un temps qui pourra être relativement long.

Jusqu'ici des états de subgravité ou de non-gravité n'ont pu être réalisés que pendant des temps très courts en faisant suivre à un avion une trajectoire

* *La Médecine Aeronautique*, 10, 309–352 (1955).

parabolique calculée à l'avance. C'est pourquoi il ne semble pas que des sujets humains aient pu expérimenter des états de subgravité ou gravité zéro pendant plus de 30 sec.

Des pilotes d'essais (Crossfield, Yeager, Murray) ont rapporté leurs sensations que l'on peut résumer ainsi. sensation d'augmentation de la [illegible]

particulières ces pilotes ont toujours été capables de continuer à piloter correctement

Des expériences animales réalisées aux USA en fusée, pendant des temps plus longs, ont montré qu'il n'y avait pratiquement aucun trouble respiratoire ou cardio-vasculaire et qu'aucun trouble de l'équilibration n'était décelable après le retour au sol.

Malgré ces données favorables, il est difficile d'extrapoler ces expériences de courte durée à des états de subgravité ou de non-gravité de longue durée Les auteurs autorisés émettent des avis différents, les uns prévoient une accoutumance humaine sans difficulté grâce à la suppléance de la fonction visuelle qui prime les autres sources d'information en ce qui concerne l'équilibration à l'état statique, d'autres craignent des troubles importants et l'établissement d'un état vertigineux profond. Il est donc nécessaire d'attendre que des expériences plus prolongées et plus complètes viennent nous éclairer sur le comportement de l'organisme au cours des états de subgravité prolongés

Problèmes Physiologiques Posés par L'Abandon de L'Avion A Très Haute Altitude

Si l'on admet que la protection de l'aviateur vis-à-vis de la baisse de pression barométrique, de pression partielle de l'oxygène, des variations de température, des vibrations transmises par l'air peut être assurée par un vêtement pressurisé et isolant, ou par un scaphandre qui joue tous ces rôles à la fois, il nous reste à étudier des aspects mécaniques de l'abandon de l'avion en vol puis de la chute libre, c'est-à-dire les pressions dynamiques et les accélérations qui s'exerceront sur un pilote dans de telles conditions

Etant donné que l'énergie cinétique de l'air répond à la formule générale $E = 1/2\ mv^2$, la pression dynamique qui s'exerce sur une surface va s'accroitre rapidement à mesure que la vitesse grandit. C'est ainsi qu'à 500 km/hr, la pression dynamique est de 1 206 kg/m^2 et à 1000 km/hr de 4 822 kg/m^2.

Au dessus de la vitesse du son la résistance de l'air s'accroit brusquement et devient plusieurs fois supérieure à sa valeur dans le domaine subsonique C'est pour cette raison que le siège éjectable est la seule méthode d'abandon d'un avion pour des vitesses supérieures à 500 km/hr, et qu'elle devient inapplicable pour des vitesses supersoniques. Deux exemples récents d' [illegible]

d'hémorragies oculaires et internes, ainsi que de lésions intestinales. La

décélération à laquelle il fut soumis a atteint 40 G. L'autre exemple est celui de M. MOLLAND, pilote de la RAF qui dut s'éjecter à la vitesse de 1100 km/hr et à l'altitude de 3000 m. En plus des hémorragies oculaires ce pilote eut à souffrir de fractures des bras et de la ceinture pelvienne. En raison de la diminution de la densité de l'air, il faut toutefois s'attendre à ce que l'éjection soit possible à des vitesses d'autant plus grandes que l'altitude d'éjection est plus élevée grâce à la diminution de la trainée. C'est ainsi que, à 5000 m, l'éjection est possible à Mach 1; à 10,500 m elle est possible à Mach 1, 5, à 15,000 m à Mach 2, à 18,000 m à Mach 2·5 (MAYO). F. HABER a calculé la pression dynamique exercée sur le corps humain à très haute altitude et pour de très grandes vitesses. Il a mis ainsi en évidence qu'à partir de 48,000 m cette pression diminuait rapidement. A l'altitude de 95,000 un pilote pourrait abandonner son avion sans le secours du siège éjectable, à une vitesse de Mach 10.

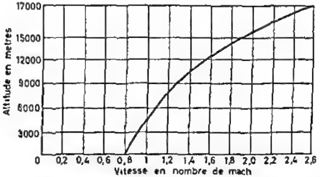

Fig 7 *Vitesses maximum pour lesquelles l'éjection est possible (d'après* MAYO).

Mais si la diminution de la pression dynamique est un facteur favorable pour l'éjection elle-même, elle devient un facteur aggravant pour la chute libre qui suit. Cette chute libre est en effet nécessaire pour de nombreuses raisons: choc d'ouverture du parachute extrêmement violent à haute altitude, nécessité de sortir rapidement des couches atmosphériques où règne un froid intense, durée limitée de l'alimentation en oxygéne de la combinaison pressurisée ou du scaphandre.

La diminution de la trainée du corps humain autorise des vitesses finales de chute libre de plus en plus élevées à mesure que l'altitude croit. C'est ainsi qu'à 30,000 m la vitesse de chute libre est de l'ordre de Mach 1. A 90,000 m d'altitude, la vitesse atteindrait Mach 3. En entrant dans les couches plus denses de l'atmosphère, le corps humain subirait une décélération qui amène sa vitesse finale de chute libre à la valeur de 160 km/hr environ quelle que soit l'altitude du saut Dans le cas de l'abandon de l'avion à 90,000 m, (en admettant une vitesse nulle au départ), la décélération atteindrait 4 G à 30,000 m. Cette décélération allant de 2 à 4 G pendant 1 à 2 min serait supportable. Les chiffres que nous venons de donner sont purement théoriques, l'abandon de l'avion de fera toujours à une vitesse élevée Pour reprendre l'exemple donné par HABER d'un pilote abandonnant son avion à l'altitude de 90,000 m et à la vitesse de Mach 10, la décélération

horizontale est au début très faible et la force de gravité diminuée par la force centrifuge due au déplacement circulaire autour de la terre. Dans ces conditions, la décélération atteindrait un maximum de 7 G environ. On voit donc que plus la vitesse de l'avion sera élevée, au moment de l'éjection, et plus la décélération sera brutale.

D'un autre côté, le corps entrera très probablement en rotation, et ces rotations feront changer constamment la valeur de la décélération en faisant varier la surface de traînée, ces fluctuations seront de l'ordre de 1 à 2 G.

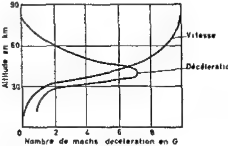

Fig 8 *Vitesse et décélération en fonction de l'altitude après abandon d'un avion volant à Mach* 10 *à l'altitude de* 90,000 m *(d'après* HABER, F)

En somme, un sujet s'éjectant à très haute altitude sera d'abord soumis à une subgravité, puis à un complexe de décélérations fluctuantes et à des accélérations en certains points du corps par suite de ses mouvements de rotation D'après HABER, ces mouvements de rotation sont favorables, car ils s'opposent aux troubles hémodynamiques qui seraient provoqués par une décélération de longue durée et dirigés tout le temps dans le même

Il semble donc, en resumé, qu'en raison de tous ces phénomènes, et malgre l'aspect favorable de certains, que la solution de l'éjection pure et simple soit à abandonner dans le cas des vols à hautes altitudes. La solution du problème réside sans doute dans la mise au point d'une cabine éjectable ou d'une capsule éjectable dans laquelle on pourrait inclure des équipements de protection nécessaires.

La cabine ou la capsule éjectable ayant une traînée plus faible que le corps humain, il serait nécessaire de les munir d'aéro-freins ou de parachutes freins destinés à éviter l'apparition d'une décélération trop importante au moment de leur pénétration dans l'atmosphère. La question

de la rotation sera peut-être la plus difficile à résoundre. Selon FROST, de l Stanley Aviation Corporation, une capsule éjectable ne serait ni plu complexe, ni plus lourde, ni plus encombrante qu'um siège éjectable lour et ne couterait vraisemblablement pas beaucoup plus cher. Elle pourrait d plus assurer la protection de l'occupant après la prise de contact avec le sol.

Dans un premier temps, il serait possible de prévoir que le pilote puiss quitter sa capsule une fois arrivé à basse altitude et prendre contact avec l sol avec son propre parachute.

Autre avantage de la capsule éjectable, qui déborde cette fois le cadre d la haute altitude, c'est qu'elle représente le seul moyen d'abandon d'u avion volant à des vitesses supersoniques à basse altitude.

CONCLUSIONS

Ainsi, le vol à très grande altitude ouvre un champ nouveau de recherches du point du vue de la physiopathologie de l'aviateur et des bases physiologiques de la protection à envisager.

Certains des facteurs de troubles organiques nous sont déjà connus, ils ne varient que dans leur importance, d'autres sont si nouveaux qu'ils peuvent étonner ceux qui n'ont pas suivi les observations concernant l'altitude et les progrès de la technique aéronautique.

Bien des bases biologiques concernant l'action sur l'organisme humain de ces différents facteurs nous manquent encore. Ceci explique que la protection de l'aviateur qui s'aventure dans cette zone de l'espace ne soit qu'amorcée.

De nombreuses recherches restent à faire, mais les problèmes sont déjà posés et certaines solutions—quoique en partie provisoires—sont déjà données.

La Médecine aéronautique, devant l'élargissement de son champ d'activité, trouve ainsi un nouvel élan de vitalité.

SUMMARY

High-altitude flight provides new research fields in the physio-pathology of aviation and in the physiological approach to protection against:

Low atmospheric pressure—*protection is required against explosive decompression and more knowledge is needed in the calculation of caloric pressures in view of hypoxic and aeroembolism hazards.*

Intense light—*the protection given by ozone and water vapour against ultraviolet and infra-red radiation is negligible at high altitudes whereas low air molecule content reduces diffusion and sky brightness.*

Spacial myopia—*the tendency to focus at short distances in empty space.*

Cosmic rays—*little is known about effects of this radiation.*

Meteorites—*the assessment of danger is yet to be done.*

Extreme temperatures—*due to altitude and aerodynamic heating.*

[illegible]

for it.

FLIGHT SAFETY—A NEW APPROACH

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THE attempt to prevent accidents must be one of the main concerns of the administration of an Air Force not only for humanitarian but also for economic reasons. In the early part of the war the accident rate from causes other than enemy action was alarmingly high. A Directorate of Accident Prevention was set up to study these facts and to recommend methods which would put a stop to this unnecessary loss of life and aircraft. Some time after the war the status of the organization was reduced to that of an Assistant Directorate within the Training Organization. The majority of the work done by these formations was backward thinking in that no action was taken until after an accident or a series of accidents had occurred. There was then a great rush to take remedial action and have the aircraft or the method of its operation modified Because of the small staff available the Assistant Directorate of Accident Prevention could only concentrate on major and minor accidents, that is, those in which a good deal of damage had been done to the crew or the aircraft. Despite this, a large amount of good work was accomplished and the general accident rate within the Air Force became lower

However the Air Council was not satisfied. It considered that the rate of wastage was still too high. As a result of several reports from pilots, doctors and other specialized people a decision was made to elevate the status of the Accident Prevention Branch to that of a full directorate and to name it the Directorate of Flight Safety. This new organization was removed from the Training Branch and is now directly responsible to the Air Council. It has direct access to all branches of the Air Force, to those people concerned with the design and development of new aircraft and to the aircraft manufacturers themselves. Into this new directorate were posted a larger number of officers, selected because of their experience in the varied flying roles and the duties connected with flying. There are qualified flying instructors, fighter, bomber, coastal and transport pilots, technical officers and even a flying doctor Coupled with these is a small group of scientists and statisticians whose responsibility it is to record all accidents that are reported and to help analyse the statistics obtained from the records.

One of the greatest changes that has occurred is the requirement for forward thinking. Very often in the past when a new aircraft type was introduced into the service, its early career was marked by a high loss of life and aircraft. Many of these disasters could have been prevented had we taken account of all occurrences in the past but because we did not, accidents were being built into these types.

With the increase in staff and experience the field of investigation has

been greatly widened. Account can now be taken of incidents in the air which have only just avoided being major crashes. Very often in a major accident where the aircraft has disintegrated the precise cause can never be dogmatically stated but when the aircraft returns after a "Near Miss" an accurate diagnosis of the cause can be made. We are of the opinion that detailed examination of near accidents will produce a large number of facts which can never be found from major accidents alone. It has been suggested that a special team should be instituted to study near accidents. This team was to have a *Flying Personnel Medical Officer;* a pilot who had operational experience and was a test pilot, preferably with an instructor's rating, and the third member was to have been a senior air traffic control officer who had a navigator's flying background. An effort was made to commence the formation of such a team and one Flying Personnel Medical Officer began training as a Flying Instructor. Unfortunately he was killed in a flying accident. There has not been any further advance with this project

Within the Directorate of Air Ministry we have been grouped into four branches. These are briefly concerned with:

1. The Flying Aspect.
2. The Technical Aspect.
3. The Scientific and Statistical Aspect.
4. Education, Propaganda and the preparation of reports and summaries for distribution throughout the Air Force.

Those in the group dealing with the flying aspect consider all the factors which are involved in the flying of an aircraft. Such factors include cockpit layout, aircraft instruments, flying proficiency and the psychological state of the aircrew. This branch is staffed by pilots with varied and experienced backgrounds and one Flying Personnel Medical Officer.

The branch dealing with the technical aspects is staffed entirely by Technical Officers whose concern it is to ensure that no technical matter which might affect the safety in operating an aircraft is overlooked.

All reports of accidents and any resulting inquiry into these are reviewed by these two branches and any faults or trends revealed are referred to the appropriate Air Ministry department for remedial action. By reference to the Statistical and Scientific Branch information can be obtained of any similar occurrences in the past and from this recommendations can be made with a view to improving design of the faulty equipment or improving the technique of the faulty operator.

The fourth branch correlates information gleaned by the Flying and Technical branches so that complete studies and statistics can be published and disseminated. This department is also responsible for the production of fil [illegible]

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with the operation of particular types of aircraft and equipment in current use within their Command. Upon these people we depend for the distribution of information to aircraft operators. One of their main functions is continually to convince everyone that Flight Safety is a matter of concern for all members of the Air Force from the Chief of Staff downwards and not just a job of work for those within the Flight Safety Organization. They are

responsible at their various levels for the co-ordination of effort towards an accident free Air Force. They must liaise with Squadron Commanders, Safety Equipment Workers and Medical Officers. Their task is not an easy one and as an aid in the future it is proposed that each of these will undergo a course of instruction in his duties. The whole purpose of the complete organization must be to integrate the operational requirement, the technical equipment and the human factors involved

More and more the Air Force is beginning to realize the absolute need for the integration of the operational requirement, the technical equipment

Some time ago a medium jet bomber was taken off from a training base for a practice sortie in radar bombing at night. The aircraft carried one pilot and two navigators On reaching the operational height for the sortie some difficulty was experienced with the radar sets and the navigators could not get clear indications of their target. This meant a considerable delay while the navigators made their adjustments and the aircraft was over the target area longer than was expected. There was an unusually large amount of clear air turbulence that night and the pilot was having difficulty in controlling the aircraft. After a short time he began to feel unwell and suspected anoxia as the cause of this but a check of his oxygen equipment revealed no fault He eventually became confused and could not relate outside references such as horizon and lights with what his aircraft instruments told with the result that the aircraft began to perform some unusual manoeuvres. Within a very short time he lost complete control and ordered his navigators to eject—an order which they acknowledged Without further ado he proceeded to attempt to eject himself, but because of the high *G* forces acting on him at the time he could not reach the handle which operated the hood jettison and the control column snatch unit. It was with the greatest difficulty that he managed to reach the ejection seat blind handle and went out through the canopy He landed uninjured by parachute; the two navigators were still in the aircraft when it crashed They had not even jettisoned their escape hatch.

The personal history of the pilot showed that he had a total flying time of 512 hr of which 13 were dual and 25 were solo on the type in which he

It was thought that on the night of the accident this pilot had not had a sufficiently good preflight briefing. For example it was felt that more emphasis should have been placed on the dangers of clear air turbulence and on the action to take when it got particularly severe.

Investigation virtually proved that the pilot was incapable of controlling his aircraft in adverse conditions. His whole past history seemed to point him out as unsuitable material for captaincy of an aircraft, yet, somehow or other he had still continued to fly. It was thought that more careful note should have been taken by subsequent supervisory authorities of the original flying training reports on this pilot and a special effort made to improve his flying or to suspend him from flying altogether.

Part of the blame could perhaps be attributed to the man's selection for aircrew. Perhaps after the initial aptitude and medical tests insufficient attention was paid to his general behaviour and bearing during the first few weeks of his Air Force life. Had such note been taken and found to be adverse then he may well never have started flying training. On the other hand there may have been some radical change in his outlook to flying after his year of enforced suspension because of illness. It is well known that many pilots have some emotional upset on resuming flying after a period of ground duties. There must have been some lack of understanding between this unfortunate young man and his instructors, which did not allow him to state his fears about flying this type of aircraft. Perhaps even his refresher course was not as complete as it should have been.

There is the background of medical unfitness in this story and it may be that if there had been complete liaison between the Medical Officer and the Squadron Commander concerned, then this man's case could have been discussed at length and a more complete picture of his capabilities could then have been formed.

It was also noted that after telling his crew to eject, this pilot then took no further interest in their well being.

I have already said that the pilot had difficulty in ejecting himself and found it impossible to jettison his canopy and it is therefore reasonable to assume that the navigators had at least the same difficulty. They had not the same advantage of Perspex canopy above their heads but had a solid piece of metal. If it was impossible for them to reach their escape hatch jettison handle, then escape for them was impossible. It is reasonable to question the design and layout of the escape control within this particular cockpit because it has been found that in an emergency, with heavy and varying *G* forces acting on him, the pilot could not reach them. If the navigators had had their hood jettison and seat firing handle combined, they they may well have escaped.

The second accident occurred some few months after the first, with an aircraft of this same type. This aircraft was piloted by an instructor and carried besides, one pupil pilot, one instructor and one pupil navigator—the purpose of the flight being to demonstrate a climb to altitude and an instrument let-down.

The take-off and climb were normal until the aircraft reached about 20,000 ft, when suddenly the aircraft began to climb at a rate which could

not be stopped by the pilot. Full forward movement of his control column seemed to be of no avail, and level flight was impossible. The only way in which he could maintain reasonable control was to keep the aircraft in a steep turn with power off. Having tried many times to regain level flight, and this being impossible, the decision to abandon the aircraft was made. Three of the occupants had non-automatic ejection seats, and the other had to make a free exit through the normal doorway after jettisoning the door. The student pilot was the unfortunate man who had to make the free escape,

but this was unsuccessful; he then bent down and assisted the pupil back inside the cockpit It was then found that a projecting handle had fouled the escapee's parachute in such a way as to tie him to the aircraft, and when this was freed the pupil made an uneventful escape, landing uninjured by parachute.

While the pupil was attempting to escape both navigators ejected themselves, one landing uninjured and the other was found dead still in his ejection seat. He had pulled his parachute ripcord, and the two lap straps of his safety harness were still fastened although his shoulder straps were free. It would appear obvious that he had ejected himself with only his lap strap fastened, and it is thought that the tumbling and rotating of the free falling ejection seat made him so confused that he was unable to locate his safety harness release box and had pulled his parachute.

The first pilot did not eject himself until all other occupants had left the aircraft. He went straight through the canopy and the first thing he did was to pull his parachute *D* ring. He realized that he had not released himself from his seat and when he did separate from the seat, the seat and parachute fouled each other. He then had to free the seat from his parachute by cutting the drogue line which was entangled with his parachute shroud lines. In all this upset the parachute was torn with the result that the pilot landed rather heavily and suffered a slight cut on his wrist.

There was no pilot error in this accident. A part of the aircraft failed

pilot in the previous accident.

Despite this, the navigator's death, the pupil pilot's difficulty in leaving the aircraft and the first pilot's tangle with his parachute and ejection seat, were all avoidable; each of these was due to faulty escape drill The pupil attempted to leave through the door by the wrong method, the navigator

escape drills. In this accident, as in the last, some difficulty was experienced in reaching canopy jettison controls, even though in the second case the forces acting on the crew members were not nearly to great or varied as in the first case. The navigators found a little difficulty in reaching their hatch jettison switch; the pilot was loath to release his grip on the control column

lest the resultant *G* forces should make it impossible for him to reach the blind handle for ejection.

Another point for consideration is the fact that the aircraft was not built for four occupants, only three ejection seats being provided, and it can be stated that the escape of the crew member without an ejection seat was entirely due to the superb airmanship of the first pilot. Further note can be made of the fact that had the navigator who died been provided with a fully automatic ejection seat, then his death might not have been inevitable.

These stories were extracted from the Courts of Inquiry which investigated the accidents. It is obvious that the cause in the first case was pilot error and the second technical failure. However, it is not sufficient to state just that. Careful analysis of all the available evidence is absolutely necessary. The reasons for the error and the failure must be deduced, otherwise no remedial action can be taken. To assist Courts of Inquiry, it is now customary for one of the Command Flight Safety Officers who has received some specialized instruction to sit on the Courts or to be in attendance to give advice when investigations are being performed. The Courts also have the services of the Accident Investigation Branch at their disposal if the cause of the accident is obscure.

Another new feature of investigation now being performed in the Royal Air Force is the automatic full post mortem examination of all fatalities by an Aviation Pathologist. From examinations such as these, Courts of Inquiry will be able more accurately to assess the causation of injuries and will be able to suggest remedial measures in many cases.

Many points arise out of the two particular cases mentioned from both the flying and technical aspects, and show the all-embracing nature of Flight Safety.

With the new organization it is hoped that in future manufacturers will be advised of basic design faults which should not be incorporated in new aircraft. By careful study of flying techniques it may be possible to advise on the method of flying training. I picked out a particularly bad example of pilot error, but there must be many cases particularly in the near accident class which point to the necessity of alteration or amplification of the training technique.

Present cockpit layout schemes and the presentation of aircraft instruments are the result of a great deal of study in the past. Much of this study was done by the Medical Branch which since its inception has been intimately connected with the prevention of accidents.

The aim must be to put a pilot in a cockpit in which he can perform his duties and give him a clear indication of his altitude and flight path which requires minimal mental and physical effort for interpretation. Many departments are still actively engaged on the problems of layout and presentation and there is need for a co-ordinating authority which will ensure that efforts are being made along convergent and not parallel paths. This co-ordination could well be done by the Flight Safety Organization.

In aircraft of the future, changes in direction and speed will be such that present instruments and layout will not be adequate when mixed power and rocket aircraft arrive. The pilot will probably be subjected to linear

and centrifugal accelerations at the same time, and the effect of such mixed accelerations on an individual are still not fully investigated. Here is the place where the Medical Branch and the designers and users of aircraft will have to get together to decide the exact limitations of a man's capabilities in view of such complications in future aircraft.

Much useful data can be obtained from details of previous accidents, and when this is correlated with experiments, medical or otherwise, then perhaps a glimpse of what will happen in actual fact will be obtained.

The time is coming when the capabilities of an aircraft *vis-à-vis* the human operator will be such that automatic controls will be necessary and little black boxes will have to perform many of the functions hitherto performed by pilots. However, it will be a long time before a black box will be able to replace completely a human being, in that there is no equivalent in weight, size and ability to think and compute as the human brain does. It may be that until such time as a robot brain is produced the pilot may only be a monitor who supervises the function of various automatic devices within his aircraft and that he will only be required to take active control of his aircraft should one or other of these fail.

We saw in the description of two accidents that difficulty was experienced by some crew members in operating their means of escape It is completely useless providing a means of escape if that means cannot be operated in an emergency. Thought on these lines should not come as a separate factor but should be considered in the basic design of the aircraft. With the advancement of aircraft speed, the limit of usefulness of the ejection seat as a means of recovering an uninjured crew member has been reached, the effect of wind blast on the pilot is such that injury is almost certain. It is admitted that limb restraint does prevent a large number of injuries, but if an ejection seat were to provide complete protection the apparatus would probably be so clumsy that the aircrew's movements would be restricted to such an extent that it might make it impossible to fly the aircraft. The necessary consideration is therefore being given to the provision of alternative means of escape such as a jettisonable capsule This would maintain the pilot or crew man in a suitable atmosphere and protect against blast effects until he reached the ground.

Pilot selection and training have often been criticized as a result of accident investigation and the need for the correlation of operational task and the

parrot fashion all the jargon necessary to indoctrinate aircrew. An instructor must be able to instill confidence in his pupils, he must be able to help them over their fears and shortcomings and he must be proficient in the art of flying and have the ability to accept or reject

Care of the psychological state of aircrew must extend beyond the Flying Training stage into the Operational stage. If the aircrew then become overworked and tired or underworked and stale, accidents will happen. The

I have tried to show you what we are doing in the Royal Air Force to prevent accidents. Perhaps our efforts will not bear any better fruits than have been borne by our predecessors in Accident Prevention, but a more positive and agressive approach has begun with the formation of the Directorate of Flight Safety and its attendant groups at lower levels. It has increased in size, and we have integrated in the new organization a variety of experience and skill. Its approach to other branches and organizations can be direct and is not hampered by being a sub-section of a specialist branch.

I would briefly summarize the duties of the Flight Safety organization as follows:

(i) It is a central reporting agency for all accidents and occurrences to aircraft or aircrew.

(ii) It is the library for all inquiries into accidents and is responsible for the follow-up of these to ensure that all remedial action to prevent a recurrence has been taken.

(iii) It has liaison with the Medical Branch so that a follow up of all medical officers' and pathologists' reports of injuries to aircrew can be undertaken with a view to re-designing personal safety equipment or altering the method of its use.

(iv) Statistical analysis and reviews of all accidents are made, so that significant trends are brought to light.

(v) It ensures that the distribution of such information gathered from these analyses and reviews is passed to all branches and commands.

(vi) It encourages the interchange of thought between the various cells of expert knowledge, so that a development of an aircraft or its components is along convergent and not parallel paths.

(vii) Publicity and education is carried out by production of articles, *films and posters to illustrate and drive home vital points.*

(viii) It has liaison with aircraft firms, designers and manufacturers so that they may be kept informed of accident potentials in their products.

Sommaire

Actuellement, dans la R.A.F., une nouvelle organisation pour la prévention des accidents aériens vient d'être mise sur pied, c'est la Direction de la Sécurité en vol—(Directorate of Flight Safety) qui relève directement du Conseil de l'Air (Air Council). Elle comprend des instructeurs de pilotage qualifiés, des pilotes de chasse, de bombardement, de transport, des Officiers techniciens et un médecin de l'Air, plus un petit groupe de savants et de statisticiens.

Son domaine s'étend non seulement aux accidents majeurs, mais aussi aux incidents aériens, souvent plus exploitables et plus instructifs. Elle comporte quatre sections s'occupant respectivement:

1°—*de l'aspect "pilotage" considérant tous les facteurs intervenant dans la conduite de l'avion: disposition du cockpit, instruments de bord, efficience et état psychologique de l'équipage,*

2°—*de l'aspect technique,*

3°—*de l'aspect scientifique et statistique, et enfin;*

4°—*de l'éducation et de la propagande par films, articles, placards, etc.*

En dehors du Ministère de l'Air, l'action de la Direction est complétée par

celle des Officiers de sécurité en vol à l'échelon de la Base Aérienne, de l'Escadre et du Command, en liaison avec les médecins de l'Air.

L'auteur rapporte dans tous leurs détails deux accidents récents, l'un du à une erreur-pilote, l'autre à une défaillance technique, qui illustrent parfaitement l'utilité de la nouvelle organisation

Les enquêtes sont actuellement complétées par une autopsie systematique, effectuée par un anatomo-pathologiste spécialisé.

Ayant constamment le regard tourné vers l'avenir, et non plus seulement vers l'étude des accidents passés, la Direction de la Sécurité en vol est à même de reviser les méthodes d'entraînement et de sélection; de coordonner les efforts pour l'amélioration des cockpits et des tableaux de bord, d'améliorer les procédés d'évacutation du bord en cas de nécessité, etc

La sélection et l'entraînement ont souvent été mis en cause. Il faut attacher une importance toute spéciale au choix des instructeurs et veiller surtout à ce que la surveillance psychologique, loin de se limiter au stade école, soit inlassablement continuée au stade opérationnel. Ceci n'est possible que par la coopération du Commandement, des Médecins et des Officiers de sécurité en vol à tous les échelons.

NAVAL AVIATION MEDICINE VIEWPOINT ON THE FLIGHT SAFETY PROBLEM

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Americans have an expression which is widely heard and prominently displayed in public places. In schools, in factories, and on the highway there are posted signs which read *Safety First!* There are active safety programmes for prevention of home, farm and industrial accidents in addition to motor vehicle and public transportation accidents. These programmes are sponsored by many agencies, both private and governmental. At the highest public level is a National Safety Council, chartered by an act of Congress, which is in a position to advise the President of the United States on all matters of public safety.

The high rate of motor vehicle accidents in America belies this basic and real concern of the people for the tragic accidental loss of life on the highways. However, one has only to look at the life expectancy of the average American to see that the individual human longevity in the United States reflects an exceptional degree of safety and physical well-being.

Turning to the subject at hand, Aviation Safety, one doubts that the Wright Brothers, or Montgolfier, Bleriot or other aviation pioneers gave more than a fleeting thought to the matter of their own safety.

Certainly in the field of military aviation and especially in wartime, the personal safety of pilots can be chiefly considered in the light of providing sufficient protective equipment and a suitable environment to promote increased performance of men and machine and thereby superiority over a real or potential enemy.

Thus, there is a fundamental difference between military aviation safety programmes and all others. in the home, in the factories, on the highways and in civil aviation. The basic concern in military aviation is *not only* to plan a programme which will *eliminate* hazardous situations *but also* one which will protect against an *increasingly* hazardous environment aloft.

The aviation safety programme of the U.S. Navy is devoted to the proposition that increasingly higher performance of aircraft need not necessarily lead to an increasingly hazardous environment aloft. In December of 1953 there was established in the Office of the Chief of Naval Operations a Division [illegible] to this

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statistics. The Division of Aviation Safety, as established in 1953, contains a [illegible] with [illegible]

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investigation; and aviation medicine.

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this activity functions as a clearing house or centralized agency for compiling and analysing all aircraft accident data.

Two principal reports are completed on every major aircraft accident—the aircraft accident report and the medical officer's report These reports are received and studied by the various departments at the Safety Center, which include Crash Investigation, Analysis and Research, Maintenance and Material, Literature, Records and Statistics and Aero-Medical. To assist in the development of data, a machine processing system is available

analysis. Nevertheless, a fairly adequate system is in operation for the

pilot-error factors Yet the flight surgeon or medical officer member of an aircraft accident investigating team has, in the past, had a tendency, at the scene of a fatal crash, to write on his report, "Injuries, multiple, extreme", and consider his job complete. Stimulated by the classic example of the British in their comprehensive medical analysis of the Comet disasters, a group of individuals in America, along with representatives from the United Kingdom and Canada, arranged a symposium in March 1955 to consider the Pathological Correlation of Aircrew Fatalities. As a result of this meeting, a Joint Committee on Aviation Pathology has been formed under the auspices of the Department of Defence with the United Kingdom and Canada as co-members.

With the establishment of the Joint Committee on Aviation Pathology, a significant step forward has been taken in the effort to clarify the so-called "pilot-error" category of aircraft accidents.

Other efforts are being made to strengthen this approach to safety. Aircraft accident investigators, flight surgeons, and the aeronautical organization in general, are becoming more and more alert to the need for comprehensive accident investigation with a view toward defining true causes and thus instituting preventive action

Another aspect of the safety programme is the preventive campaign in itself. A major development in this regard was the establishment of a Naval Aviation Safety Officer Course at the University of Southern California in the fall of 1954. The curriculum of 264 class hours includes courses in the following.

1. Aeronautical Engineering — 101 (class hours)
2. Aircraft Accident Investigation — 74 " "
3. Safety Management (included in courses 2 and 6)

4. Aviation Psychology	30 (class hours)
5. Aviation Physiology	27 " "
6. Education	32 " "

In 1955 there were 125 officer graduates of this course who were assigned as staff and squadron safety officers upon graduation.

These graduates are regarded as specialists in aviation safety and are expected to make a major contribution to the programme throughout the aeronautical organization. They are assuming roles of leadership in the various staff and area safety councils located in the Naval Districts and

Operations Aviation Safety Council meets at frequent intervals to consider major aspects of the programme.

These are a few of the major developments in the field of aviation safety within the past few years. It is difficult at times to distinguish between the subject of aviation safety and the maintenance of a high degree of combat readiness. Yet a successful or completed mission is a *safe* mission. You are all aware of the many aspects of aircraft performance and the measures required to keep the aviator abreast or "ahead of his machines". At first glance it might appear as though the capabilities of the aircraft had outstripped the capabilities of man to control and operate it safely. Aircrew equipment laboratories are hard-pressed to develop the equipment and environment ... which will render ... "by the seat of ... idence that we are making progress in this regard are the following figures: the Navy major accident rate for the years 1949 through 1953 was 5·5 major accidents per 10,000 hours of flying, the average for 1954 was 4·42 and for 1955, 3·56. Also the application of the British development of the canted or angled deck and the mirror landing device to our aircraft carriers is aiding greatly in reducing accidents. In addition to overall safety records study, detailed studies of accident records of particular aircraft are made in order to assist in improvement of aircraft and related components. Analysis of wheels-up landings, ejection seat performance and the like have contributed greatly to progress in improving safety and decreasing accidents, injuries and fatalities.

The following analysis of ejection seat usage in the U.S. Navy gives an indication of such progress and the influence of statistics on design development.

From the time of the first emergency escape from a Banshee fighter aircraft on 9 August 1949, to the first of January of 1956 there have been 177 ejections from Navy aircraft.

Before proceeding to a brief analysis of Navy ejections, I should like to interject a word of caution regarding the strict application of statistical methods to the figures which will be presented. There are many variables involved in any successful ejection; the principal ones being:

(1) the condition of the aircraft, including its altitude and speed.

(II) the functioning of the ejection seat mechanism, including separation from the seat and deployment of the parachute and

(III) the reactions of the pilot, including his decision to eject and his ability to complete the required procedures.

It is difficult in each instance of ejection, where the pilot has not survived, to isolate the variable or variables at fault For this reason, each individual ejection should, by and large, be considered as an occurrence in itself for purposes of safety study and preventive action. Furthermore, it is not possible, in a series of only 177 cases, to be on firm statistical ground.

Nonetheless, one fact appears to stand out, namely the fact we have at our disposal (*Fig.* 1) a highly successful means of escape from disabled or

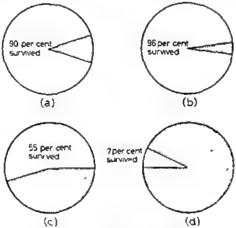

Fig 1 *U.S Navy Ejections*
(*a*) *Speed below* 400 *knots* (*b*) *Altitude above* 5000 ft.
(*c*) *Speed above* 500 *knots* (*d*) *Altitude below* 1000 ft.

uncontrollable aircraft *under certain conditions*. (In the upper left-hand corner) out of 136 ejections below a speed of 400 knots, 123 or 90 per cent of the pilots have survived (In the upper right-hand corner) out of 106 ejections above 5000 ft altitude, 102 or 96 per cent of the pilots have survived Lest these figures lead us to complacency regarding our present equipment and its capabilities, however, we hasten to observe (in the lower left-hand corner) that out of 9 ejections at speeds of 500 knots and higher, there have been 5 survivors—approximately half, as compared to 90 per cent at the lower speeds. And (in the lower right-hand corner) out of 14 ejections below an altitude of 1000 ft, there was only one survivor—7 per cent survivability compared to 96 per cent at altitudes above 5000 ft.

It is not necessary to emphasize that our experience with ejections from high-speed aircraft is only beginning. Nor is it necessary to point out that there are a number of extremely low altitude or ground level emergencies such as flame-out on take-off or landing which result in fatalities, yet which are *survivable*—provided we have equipment with the capability of safe ejection at ground level.

In the summary of Navy ejections which follows (*Fig.* 2) only successful ejections are included—by "*successful*" we mean that the pilot is known to have ejected and cleared the aircraft prior to impact with the ground. Known "attempted ejections" are excluded. Also obviously excluded are an unknown number of fatal cases wherein attempts to escape may have occurred.

Out of 177 ejections, 115 or 65 per cent resulted in minor or no injury to the pilot. Twenty-seven or 15 per cent resulted in serious injury to the pilot. A total of 142 or 80 per cent of the pilots survived their ejections.

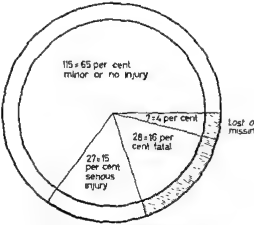

Fig. 2. *U S. Navy Ejections.*
Total to 1 Jan. 1956 = 177 Survived 142 = 80% Fatal 35 = 20%.

Seven or 4 per cent of the pilots who ejected were reported as lost or missing. And 28 or 16 per cent of the pilots were fatalities. Thus a total of 35 or 20 per cent of all ejections were considered fatal.

Out of 35 fatal ejections, 26 or 74 per cent were attributed to one or the other of the following causes· did not leave seat, rip cord not pulled, chute not deployed or impact with ground.

Twenty-two or 63 per cent of the fatal ejections were accomplished below 3000 ft. This fact, coupled with the previous cause factors, would suggest that 3000 ft *is perhaps the critical altitude, below which* there is insufficient time for the pilot to accomplish the entire ejection sequence including separation from the seat and deployment of the parachute.

It has been estimated that safe ejection may be accomplished at *200-300 ft* when the automatic seat belt and parachute opening devices are standard equipment. Present figures may tend to make this prediction sound somewhat optimistic.

Figure 3 re-emphasizes the point that was made earlier. Although our experience with ejections over 500 knots is small the next few years will probably show a shift of the larger bars to the right of this slide.

Also, the larger bar representing the unknown cases may very possibly be properly located on the abscissa as you see it on this figure, since at the lower speeds the outcome is uniformly more favourable.

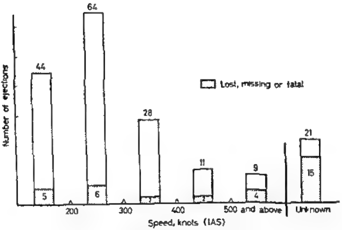

Fig 3 U.S Navy Ejections Speed and Survivability
Total to 1 Jan 1956 — 177

Figure 5 compares the cause for ejection and survivability and also shows the causes for ejection in the order of their relative frequency, fire, explosion, loss of control, etc.

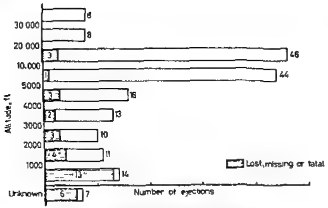

Fig 4 U.S Navy Ejections Altitude and Survivability
Total to 1 Jan 1956 = 177.

One might point out that in the cases of loss of control, indicating perhaps the extreme cause for ejection, survival was 33 out of 43 or 76 per cent.

While in relatively controlled emergencies such as engine failure and fuel exhaustion, survival was 33 out of 34 or 97 per cent.

Finally, your attention is called to the small bar on the right-hand side of *Fig.* 5 which indicates that there has been only one inadvertent ejection. This emphasizes the use of accident statistics in guiding design requirements.

With the first installation of the ejection seat, there was considerable concern about possibilities of inadvertent ejection of the seat in flight, or accidentally on the ground or during maintenance procedures. The face curtain firing method basically was considered to be of advantage, in this respect as it was located in an area not conducive to being caught by clothing or equipment when entering or leaving the aircraft, nor was it likely to be confused with other items in the cockpit. Nevertheless as an extra precaution in earlier installations, a separate pre-ejection lever to jettison the canopy and

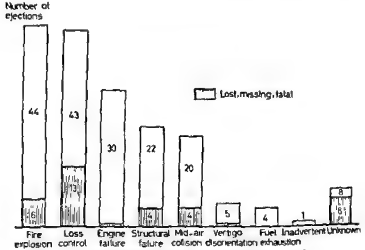

Fig. 5 *U.S. Navy Ejections Cause for Ejection and Survivability. Total to* 1 *Jan* 1956 = 177.

arm the seat was used. The seat subsequently fired by the face curtain which also aided proper body-positioning and support during ejection and the

ditions. Since the face curtain is essentially a safe system in itself the pre-ejection lever as such is no longer considered necessary and its functions are now included in the face curtain firing sequence. This is designated as single-point ejection control The first part of the travel of the face curtain actuates jettisoning of the canopy which pulls the safety pin of the catapult and the seat fires as the face curtain completes its travel downward.

It is to be noted that the seat cannot be fired until the canopy is jettisoned and thus pulls the seat catapult safety pin. This provision was incorporated to prevent premature ejection through a closed or partially opened canopy. However, the record seemed to indicate more of a problem through failure

ejection through the canopy is possible. To date the Navy has had seven successful intentional ejections through the canopy with only minor injury.

The considerable success of the ejection seat as a method of escape from high-performance aircraft has thus shifted the emphasis in system design from one of caution against ground ejection or inadvertent ejection to a more correct emphasis on proper functioning under emergency conditions. Incorporation of an alternate means of removal of the safety pin in the event of failure of canopy jettisoning reflects this change and has resulted in seven successful ejections through the canopy. Incorporation of single-point ejection control is also designed to favour escape under emergency procedures by eliminating an extra step in the procedure and by simplifying design. Improvements in design have also been accomplished to eliminate possible mechanical failures or maintenance difficulties.

The major remaining area for reduction of fatalities lies in increasing the possibility of successful escape at low altitudes and at very high altitudes and high speeds, particularly through incorporation of automatic lap belts and parachute opening devices. These are going into all our aircraft as rapidly as possible

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Throughout the evolution from improved bailout procedures to ejection seats and on into ejection seat capsules, flight safety and accident statistics have thus played an important role.

Continued effort is being made to obtain accurate data regarding aviation accidents and their causes and to utilize this in aircraft design, training programmes and operational procedures.

However, in one particular area, greater emphasis is required The shortage of adequate numbers of career flight surgeons combined with the effects of the rapid turnover of doctors entering and leaving the service under the doctor draft and the heavy medical workload, have handicapped the programme of preventive aviation medicine Flight surgeons all too often do not have sufficient time to spend with their pilots and aircrewmen. However, it is hoped that in the not too distant future this will be remedied. Greater attention by flight surgeons to details of living of their pilots, training and equipment is required It is of course far better to prevent accidents than to investigate them

In summary, safety is emphasized on all levels throughout the Navy with particular emphasis through the Aviation Safety Division in the Chief of Naval Operations, the U S Naval Aviation Safety Center, and the Aviation Safety officers who are assigned to operational commands and individual squadrons Safety information and crash investigation data are used in aircraft and aircraft component design and development to improve safety with minimum limitation on operational performance of aircraft.

This programme should insure the optimum in safety of flight while developing the maximum in operational and combat readiness of the aviation units of the U S. Navy and Marine Corps.

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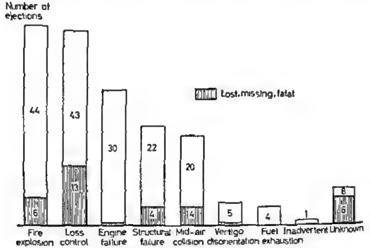

Fig 5 U S Navy Ejections Cause for Ejection and Survivability.
Total to 1 Jan 1956 = 177.

arm the seat was used. The seat subsequently fired by the face curtain which also aided proper body-positioning and support during ejection and the retention of oxygen mask and helmet after ejection.

Although this system proved to be safe in flight, its extra safety factors may have introduced undesirable features in escape under emergency conditions. Since the face curtain is essentially a safe system in itself the pre-ejection lever as such is no longer considered necessary and its functions are now included in the face curtain firing sequence. This is designated as single-point ejection control. The first part of the travel of the face curtain actuates jettisoning of the canopy which pulls the safety pin of the catapult and the seat fires as the face curtain completes its travel downward.

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However, in one particular area, greater emphasis is required. The shortage of adequate numbers of career flight surgeons combined with the effects of the rapid turnover of doctors entering and leaving the service under the doctor draft and the heavy medical workload, have handicapped the programme of preventive aviation medicine. Flight surgeons all too often do not have sufficient time to spend with their pilots and aircrewmen. However, it is hoped that in the not too distant future this will be remedied. Greater attention by flight surgeons to details of living of their pilots, training and equipment is required. It is of course far better to prevent accidents than to investigate them.

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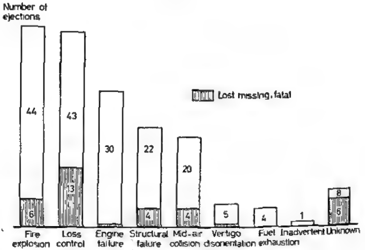

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Safe escape in many instances from high-performance aircraft will require an exploitation of the above along with possible use of auxiliary methods of slowing the aircraft prior to ejection at very high speeds Beyond this in still higher-performance aircraft use of cockpit capsule type escape appears essential if high fatality rates are to be avoided

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Sommaire

Dans la Marine américaine, le Chef des opérations navales dispose d'une "Division de sécurité aérienne" avec un Directeur et 5 Officiers. Elle a elle-même sous son autorité technique le Centre de sécurité aérienne de la Marine à Norfolk (Virg.) avec 85 personnes, qui centralise et analyse tous les rapports d'accidents. (Rapports d'accidents aériens et rapports des médecins). Ce Centre travaille en liaison avec le Comité mixte d'anatomo-pathologie de l'aviation, créé en 1955 par le Département de la Défense.

Il est admis que 50 à 65 pour cent des accidents aériens sont certainement dus à une "erreur-pilote". C'est à l'étude et à l'analyse de ce facteur que tendent les efforts actuels dans un but de prophylaxie. L'université de Sud-Californie a été chargée d'un cours d'Officiers de sécurité aérienne avec 264 heures de leçons. En 1955, 125 Officiers ont été diplômés et affectés dans les Etats-Majors et les Groupes aériens, où ils forment la véritable ossature de l'organisation.

Le taux des accidents graves qui était de 5·5 pour 10,000 heures de vol en 1953, est tombé à 4·42 en 1954 et à 3·56 en 1955.

cent des pilotes ont survécu, dont 15 pour cent au prix de blessures graves. Dans les cas où la cause de l'éjection était la perte de contrôle de l'appareil, la survie fut de 76 pour cent, tandis qu'elle a atteint 97 pour cent quand il s'agissait d'accidents "relativement contrôlés", tels que panne de moteur, panne de combustible, etc.

THE SUMMATION OF SOME PHYSIOLOGICAL FACTORS LEADING TO INCIDENTS IN THE AIR

W. R. Franks, RCAF

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Within a few months we have been able to collect a total of nine reasonably well authenticated cases of loss of effective consciousness occurring among aircrew while in the air. By a combination of either amazing good luck, or due to the fortuitous presence of a second person who could take control of the aircraft, these happenings have not proved fatal. The incidence of these episodes and the information gained from examination of the circumstances, which is possible due to survival of those involved, would suggest that mechanisms so disclosed form the basis of the distressingly frequent occurrence in all modern air forces of fatal accidents in which everything points to failure of the human factor. The aircraft usually flies straight into the ground and no attempt is made to use the ejection seat when available. Loss of useful consciousness is indicated.

The healthy individual is apt to take consciousness for granted but actually of all physiological processes it is in many respects the most tenuous. The normal oxygen debt of the brain only suffices for six useful seconds, yet at the same time the normal blood flow required by the functioning brain is ten times that of the remainder of the body on a weight for weight basis. Such are the vicissitudes of the mechanism and controls involved that any normal healthy individual can be made unconscious by a relatively simple combination of procedures. Thus squatting and hyperventilation followed by raising to the erect posture and performing the valsalva manoeuvre uniformly causes normal individuals to faint (Sharpey-Schafer E P 1951–1956).

To those who have experienced this, the sudden loss of a period of time out of one's consciousness can be a very perplexing, if not shaking event

followed natural causes which once recognized can be prevented

In reviewing our short series of cases several pertinent factors are brought to light which when considered in the terms of modern physiology, enable one to picture the probable nature and cause of the incident. Loss of useful consciousness in the air quite possibly represents the paramount aviation problem facing us today In our series eight of the nine occurred on high-performance jet aircraft, six out of the nine pilots having had 1000 hr or more flying time to their credit In seven out of the nine there was an

element of either anger or apprehension associated with the episode. Fiv of the nine were salvaged to return to full flying duties. The intimate histor and the findings indicated in practically all cases that the final loss of consciousness was associated with a combination of physiologically active circumstances which summated in their effect to produce the total disability. In this paper we propose to review briefly something of our knowledge of the various factors which can take part in this net effect which can prove so embarrassing in the air.

in the RCAF today. Nevertheless the partial pressure of oxygen at the tissue level is one of the fundamental parameters of brain function. Continued second-to-second utilization of oxygen is a necessity for the normal function of the brain. Small reductions in oxygen supply may actually increase activity as measured by reaction time or accommodation but even at levels of 10,000 ft equivalent the rate of development of fatigue is increased. In addition to the well-known reduction in night visual acuity, DUGAL (1957) has been able to show that memory as measured by the rate of learning is decreased at these levels. Thus it is more difficult for a member to do the right thing in regard to other factors concerned with our problem when even mild degrees of hypoxia are present.

Hypoxia can also play an associated role by producing a sense of air

delivered. In this connexion it is of interest to note that GROSSI-BRANCI (1955) has been able to revive cortical activity in a shocked animal as measured by the e e g as a result of increased uptake of oxygen from the blood by the tissues following the administration of a cytochrome-*C* preparation

Finally the oxygen picture may play a role in the elements going to produce aero syncope as a result of the paradoxical response to sudden restoration of adequate oxygen levels following a period of hypoxia. The net physiological effect has been shown (SCHWARZ 1936, GRANDPIERRE *et al.* 1952, and STAVRAKY 1945) to resemble that of a Bezhold-Jarish response, namely, slowing of pulse, fall of blood pressure and inhibition of respiration There can be no doubt that the efferent pathway of the cardiac effect is mediated through the vagus but the fundamental centre from which this response is initiated remains to be determined. It is possible that central hypoxia secondary to acapnic changes may also predispose to this effect on the sudden restoration of normal tissue oxygenation. Such a response may be a fundamental one since BRONFMAN *et al* (1956) have recently shown that ectopic ventricular arrhythmia can be initiated by the localization restoration of normal oxygenation to heart muscle triggering ectopic responses in asphyxiated myocardium.

In one of our cases syncope followed the actuation of the press-to-test button on the A 20 regulator which releases a mild surge of 100 per cent

oxygen. Although there are other factors in this case (POWELL 1956) certainly timewise the syncope was related to the sudden release of the 100 per cent oxygen.

The other chemical substrate on which the brain is dependent for its

between seven and eight o'clock on the morning of a day of difficult flying.

There can be no doubt that the normal functions of the brain are immediately dependent on an adequate supply of glucose but it is likewise obvious that this relation is not always a direct one. The situation has been reviewed in the paper by FABRYKANT and PACELLA (1948). Otherwise normal indi-

glucose CONN and SELTZER (1955) have suggested that the compensatory hyperepinophrinemia may be the variant on this. There is a need for adequately controlled experiments in this field, and we are currently determining the effects of ingestion of a bland intake (methyl cellulose) as compared with glucose, using the e e g change and tremor test as criterion.

It is obvious, however, that the poor homeostasis of blood sugar, which is so vital for cerebral functioning, can play a real role in predisposing normal healthy individuals to nonoptimum function during the periods of hypoglycemia Thus TUTTLE *et al.* (1949) were able to show in a group of normal University students that a "coffee only" breakfast (plus 1 oz cream and no sugar) as compared with a light breakfast, resulted three hours later in significantly increased neuromuscular tremor and choice reaction time coupled with diminished maximum work output. There can be no doubt but that the performance of the average individual varies with the blood sugar, but Tuttle found there was considerable variation in the susceptibility between different individuals In our series two of the nine gave a blood sugar of less than 70 mg per cent total reducing substance within 2 5 hr in the glucose tolerance test and in a third a flat curve was obtained which reached approximately 70 mg total reducing substance within 1 hr of the glucose feeding

It is now apparent that there are a number of factors which can influence the degree of "functional hyperinsulinism" as described by CONN and SELZER (*ibid.*). The character of the meal can have a considerable effect. It is known that the rate of absorption of sugar is a factor in calling forth the production of insulin and that this is influenced by the amount of carbohydrate in the diet and by the rate of emptying the stomach Thus a high protein, low carbohydrate breakfast has been proved to be effective, prophylactically, in established cases of functional hypoglycemia. Absorption of sugar is from the small bowel and thus the rate of absorption can be controlled by, among other things, the rate of emptying of the stomach (EVENSEN 1942). This may prove of particular interest to our problem due to the possible increased flow of gastric contents through a relaxed pylorus while under prolonged increased positive acceleration. Two of our cases gave a history of repeated

turns producing accelerations up to 4 G (firing exercises) without G-suit protection. We have recently failed to induce a low blood sugar in a pilot with a gastrectomy, following glucose feeding coupled with runs on the centrifuge, although we likewise failed to produce symptoms of the "dumping syndrome" in this case (see HAYES 1955). Apart from the well-known factors controlling blood sugar (CONN *ibid.*; McQUARRIE 1955), including food, adrenal insufficiency, hypothyroidism or even convalescence following hepatitis, the pancreatic substance glucagon which causes glycogenolysis may be involved. The precocious mobilization of glucose precursors may ultimately lead to exhaustion phenomena. As pointed out in the recent review of PINCUS (1956), there is evidence that glucagon elaboration may be under the control of the pituitary growth hormone.

The recent evidence that various substances can cause effective hyperinsulinism by inhibiting the enzymes which naturally destroy the hormone, is also of interest. MIRSKY (1956) has recently reported that a stable peptide can be extracted from liver, which acts as a competitive inhibitor of insulinase. Apparently such a simple substance as tryptophane is active There thus is a number of possible factors influencing the mechanism which control blood sugar which warrant attention in the light of our problem.

As CONN (*ibid.*) has pointed out, one of the consistent symptoms associated with hypoglycemia is a sense of insecurity if not apprehension. The superimposition of such a state on the already considerable stress that may arise in modern flight conditions could well serve to set up a vicious circle serving to accentuate any latent autonomic instability in an otherwise rugged individual (PORTIS 1950). Current evidence on this subject has recently been reviewed (LANCET 1956). Finally, as VAN WULFFTEN PALTHE (1953) [illegible]

[illegible] ng flight [illegible] -chanisms are involved. Associated with acapnia there is a vasoconstriction of the cerebral vessels, and this response is in many respects unique. In addition, there is good evidence to show that hyperventilation also causes a vasodilatation with increased pooling of blood in the muscles. While actual unconsciousness can result from this combination of circumstances, even mild responses leave the normal individual particularly susceptible to other factors such as hypoxia or increased intrathoracic pressure of pressure breathing or even pressure override systems as SHARPEY-SCHAFER (*ibid.*) has pointed out.

When we further consider that the alkalosis associated with this acapnia may well shift the hemoglobin dissociation so as to interfere with oxygen delivery to the cells, the sinister possibilities of an element of hyperventilation becomes evident. Hyperventilation is difficult to diagnose *post hoc*, but there was suggestive evidence from history and subsequent behaviour in the decompression chamber that this factor played some role in the syncopal incidents in at least four cases out of the nine in our series. As SHARPEY-SCHAFER (*ibid.*) has pointed out, a rise in intrathoracic pressure causes a

decrease in the filling pressure of the heart by trapping blood behind closed venous valves The amount of decrease depends on the degree of pressure breathing and the previous state of vasomotor tone. Peripheral vasodilatation [illegible]

as a result of the press-to-test button on the A20 regulator resulted in a syncope lasting for probably 5 min.

As HENRY (1951) has pointed out pressure breathing in the unprotected [illegible]

serious when combined with the other factors at present under consideration.

Excessive heat due to possible failure or inadequacy of the cockpit cooling system in modern high-performance aircraft is a condition which has to be faced Again the physiological response is unfortunate. Not only is there a shift of blood into the peripheral areas but if the heat is excessive vaso-vagal effects can be anticipated. No doubt such a circumstance combined with [illegible]

situation

That high positive acceleration can produce profound alterations in the blood flow to brain is well known but from the foregoing consideration it is obvious that relatively small increases in positive G can be likewise profoundly effective when coupled with other mechanisms which act similarly. [illegible]

Increased heat and acceleration in our hands have been shown to be a particularly embarrassing combination.

[illegible]

It must be remembered that normally when a man faints he falls to assume the reclining position. To a pilot harnessed to his seat this effective measure is not possible There can be no doubt that even under 1 G the forced retention of a sitting upright position during syncope can only serve to prolong or otherwise aggravate the situation. Increasing the G only serves to add further insult. In two of our cases there is good evidence that the syncope in the pilots lasted for several minutes. Longer than we might expect in a healthy young adult There is need for further study of this effect of the crash harness.

Fortunately in all this the use of the G-suit provides a valuable defence no matter what the cause of the diminished cardiac filling pressure. Inflation really is physiologically equivalent to the normal baroceptor constriction. In our hands the effect of inflating the G-suit even to approximately 40 mm Hg under 1 G, provides a dramatic relief in a variety of syncopal conditions including that due to pressure breathing, heat syncope and even post influenzal hypostasis, as well as increased G. Inflation of the suit to 40 mg in a normal individual produces changes which resemble the classical Bainbridge reflex of animals, that is, there is a rise in pulse rate and blood pressure, with an increase in respiration. Inclusion of the arms as in the partial pressure suit of course simply makes the system more effective.

Vertigo from disorientation can likewise cause a reduction in blood flow to brain as SPIEGEL *et al.* (1944) have shown experimentally in cats. This is apparently a passive phenomenon secondary to a splanchnic dilatation Evidence that a similar mechanism is active in man is shown by the EEG changes associated with vertigo (see BEHRMAN 1955). In at least two of our cases the final event seemed to be triggered by the imposition of Coriolis effect due to rotating the head while in a turn. Sudden bumps of negative G can also act on the baroceptors behaving like Sharpey-Schafer's imposed transients and result in a vasodilatation a few seconds later, at which time this may constitute an embarrassment

Flicker syncope is another type of response which can occur in the air. The frequency concerned, between 10 and 100 msec, is not liable to be encountered in jet aircraft but it undoubtedly can be a problem in helicopters. We ourselves have uncovered a case similar to that reported by VAN WULFFTEN PALTHE in which the pilot fainted while landing into the sun with the propeller idling In our case the aircraft had not landed but the situation was retrieved by the co-pilot.

It must be realized that visual impulses are not the only stimuli which can elicit this response. Intermittent loud noise of the proper frequency can be effective and "beats" of this order can occur in the cockpit of jet aircraft [illegible]

welcomed as to the possible factors which may alter sensitivity from time to time. The final response has all the characteristics of a classical vasovagal attack.

In addition to the foregoing "physiological" responses which act more or [illegible]

[illegible] ...oning with various cockpit atmosp[illegible] carbon monoxide and toxic break- [illegible] jet engine lubricants.

Alcoholic hangover must be recognized as one of the facts of life among aircrew and was the fundamental cause of at least one of our cases which did not prove fatal for the simple reason that a co-pilot was available. The incident occurred after about 1 hr flying time from take off on a warm day, flying into the sun with the pilot of course strapped sitting upright. There

is urgent need for a more serious study of this problem utilizing modern [illegible]

[illegible]

following a 6 G turn without protection. On coming to, there was the usual sweating, paleness (movies were being taken at the time) with feeling of nausea and general debilitation. No alcohol had been taken for at least 10 hr previous to the flight but the same cannot be said for the period preceding this. The response would appear to be vasovagal in nature and can be largely prevented with modern G protection.

Carbon dioxide in small amounts actually increases the blood flow through the brain as PATERSON (1955) has shown. The effect is the reverse of the acapnia of hyperventilation Higher concentration of carbon dioxide, however, can act locally to interfere with cerebral functioning behaviour in many respects like an anaesthetic.

Carbon monoxide of course interferes with the delivery of oxygen to the brain and therefore may be regarded as a particular type of hypoxia. How important the substance may be in the operation of modern jet aircraft while wearing oxygen equipment is at present a subject for some debate The high incidence reported *post mortem* by CLARK *et al.* (1955) in fatal crashes might be expected to have its counterpart in non-fatal incidents where an opportunity of examining the patient and the circumstance is afforded. In the RCAF within recent months we have had only one case, an observer in a two-passenger jet aircraft who became unconscious at altitude while wearing an A13 oxygen mask into which he was found to have vomited (and not removed). He remained unconscious for some time after landing, was admitted to hospital and 24 hr later a blood sample sent to the provincial laboratory was reported to have had 30 per cent monoxy hemoglobin. Unfortunately the test was not repeated to confirm. The pilot of the aircraft was not himself affected.

The case itself was thought at the time to have been one of aero-embolism which of course can produce all degrees of interference with consciousness In such cases it is usual that at least some disability persists after recompression Aero-embolism was a very fashionable subject for aviation medical research during the last war but rather fell into disrepute when the operational importance of the hazard did not develop. [illegible]

[illegible]

contaminate the cockpit in various ways indicates the necessity for further

investigation of these materials (KITZES 1956). One of our cases occurred after a reported cockpit contamination with a peculiar odour "like burning plastic". The syncope lasted for several minutes. It is possible that some of

its consequences serious enough that official cognizance of the hazard should be taken. As SHARPEY-SCHAFER points out the differentiation from epilepsy, although difficult, is often not insurmountable. The need of a close history must be stressed. Syncope may be differentiated from epilepsy by the fall in blood pressure at the time of loss of consciousness which fall may be spotted *post hoc* due to the diminished secretion of urine for several hours following. Pallor also persists for some time but if the incident in the air is not fatal, the circumstances, no matter what the initial cause, are such that any individual is apt to be pale and have marked tremor when examined on landing. We at present in the RCAF are in the process of drafting a questionnaire to be filled out as soon as possible after such episodes.

Furthermore, there is need for the briefing of the control tower on emergency procedures which should be adopted. Landings are apt to require special consideration, the individuals concerned being naturally in a highly emotional state following a physiological near-miss.

For the immediate treatment in the air the oxygen system combined with the G-suit or the pressure suit offers valuable and dramatic aid. Manual inflation of the G-suit to "comfortable" levels of pressure provides an immediate relief which has to be experienced to be believed. For hyperventilation, we have hesitated to add carbon dioxide to the energency oxygen system due to the reported incidence of ventricular fibrillation induced thereby. On reviewing the literature, however, it is apparent that fibrillation only occurs after rather prolonged periods of hyperventilation such as during anaesthesias of long duration. Such duration is not liable to occur in the air and perhaps the matter should be reconsidered. To ask a layman to differentiate between hypoxia and hyperventilation effects is not realistic and holding the breath during hypoxia can produce sudden unconsciousness. Perhaps the answer lies in first checking the oxygen system, breathing normally and then exercising the muscles. Overbreathing is only hyperventilation in the absence of exercise. As RAKESTRAW (1921) has shown, mild exercise can actually raise the blood sugar level.

Syncope is always associated with a loss of muscle tone and perhaps this mechanism could somehow be used to trigger off a safety procedure. The

There were three times as many deaths from air accidents as from po-myelitis in Canada last year. Most of these are preventable. Perhaps the seriousness of the problem warrants the consideration of a deadstick aeroplane. In seven out of nine of our non-fatal cases, unconsciousness lasted less than 1 min.

Recommendations covering these considerations might warrant the attention of this advisory group.

Sommaire

L'étude d'une récente série de neuf incidents aériens où, grâce à des circonstances heureuses la perte de connaissance ne fut pas suivie de mort, permet de penser que la même cause a provoqué de nombreux accidents mortels restés inexpliqués. La dette normale d'oxygène de la cellule cérébrale n'est que de six secondes; la perte de connaissance en l'air constitue un problème vital de médecine aéronautique.

Un certain nombre de facteurs ont pu être dégagés de cette étude, et c'est leur combinaison ou leur sommation qui s'est révélée néfaste.

L'hypoxie *grave en elle-même est une cause rare d'accident. Mais l'hypoxie légère augmente la fatigue, diminue la mémoire et l'acuité visuelle nocturne, et d'une façon générale sensibilise l'individu à l'action des autres facteurs nocifs du vol Subjectivement ressentie elle provoque l'hyperventilation L'"effet para-*

etc. En tout cas l'hyperglycémie s'accompagne toujours d'une sensation subjective d'insécurité et d'appréhension, qui s'ajoute aux autres facteurs de stress pendant le vol.

tion de l'hématocrite traduisant une extravasation plasmatique intense dans l'inhalation sous pression sans contre-pression

La chaleur excessive *par panne du système de réfrigération du cockpit est à considérer.*

Les accélérations positives, *même relativement peu élevées, constituent un facteur certain d'aggravation. La simple station debout* (1 G) *peut amener la syncope, et alors la chute sur le sol est un phénomène de défense le pilote sanglé, buste droit, sur son siège, en est privé Heureusement le vêtement anti-G peut ici remplacer la vaso-constriction normalement déclenchée par les barocepteurs.*

Le vertige *par désorientation avec, dans deux cas, l'accélération de Coriolis par mouvement intempestif de la tête, ainsi que d'autres stimuli non visuels, peuvent également intervenir*

A côté de ces réponses dites physiologiques, l'auteur souligne encore trois facteurs qui, bien que banaux, ne sauraient être négligés·

—l'imprégnation alcoolique, qui en dehors même de l'action aiguë (pharmacologique, dit le texte) de l'alcool, a un effet prolongé,

—l'anhydride carbonique et l'oxyde de carbone, ainsi que les produits de décomposition des lubrifiants des réacteurs,

—Enfin l'aéroembolisme, s'il n'a pas été retrouvé dans la série d'incidents relatés, doit être soupçonné dans certains accidents mortels récents.

En résumé, la syncope en vol n'est pas rare. On peut par l'anamnèse la distinguer de la crise épileptique. Son traitement, en l'air, consiste dans le gonflage manuel du vêtement anti-G à un niveau "confortable" qui s'est révélé très efficace, et l'inhalation d'O_2 avec ou sans pression. La tour de contrôle doit guider soigneusement l'atterrissage, toujours précaire après une syncope. Au sol, le traitement consistera en inhalation de O_2 avec 3·5 pour cent de CO_2 pour lutter contre la perte du tonus musculaire.

Bibliography

Behrman, S. "Vestibulary Epilepsy". *Brain* 78, 471, 1955.

Bronfman, B L., Leighninger, D. S. and Beck, C. S. "Electric Instability of the Heart. The Concept of the Current of Oxygen Differentiation in Coronary Artery Disease". *Circulation* 13, 161, 1956.

Clark, R. T., *et al.* USAF School of Aviation Medicine, Randolph Air Force Base, Texas, 1956

Conn, J. W. and Seltzer, H. S. "Spontaneous Hypoglycaemia". *Amer. J. Med.* 19 (3), 460, 1955.

Dugal, L. P. and Fiset, P. E. "Sensibility of Man to Light Anoxia". *J. Aviat. Med.* 21, 362, 1950.

Ernsting, J. (Abstracts). *J Aviat. Med* 27, 164 and 165, 1956.

Evensen, O. K. "Alimentary Hypoglycaemia after Stomach Operations and Influence of Gastric Emptying on Glucose Tolerance Curve". *Acta med. scand.* (Supp) 126, 388, 1942.

Fabrykant, M. and Pacella, B. L. "Association of Spontaneous Hypoglycaemia with Hypocalcemia and Electrocerebral Dysfunction". *Amer med Ass. Arch. int. Med.* 81, 184, 1948.

Franks, W. R., Lennox, C. S. and Shimizu, T. "Post mortem detection of Anoxia as a Cause of Fatal Accident". *J. Aviat. Med.* 24, 147, 1953.

Grandpierre, R and Franck, C "The Paradoxical Action of Oxygen". *J. Aviat Med.* 23, 181, 1952.

Grossi-Branci, M. L. (Abstract). "Electroenceph. Clin." *Neurophysiol* 7, 447, 1955.

Hayes, M. A. "Dietary Control of the Post Gastrectomy 'Dumping Syndrome'." *J. Amer. dietet. Ass.* A31, 133, 1955.

Henry, J. P. "The Significance of the Loss of Blood Volume into the Limb during Pressure Breathing". *J. Aviat Med.* 22, 31, 1951.

Kitzes, G. "Cabin Air Contamination Problems in Jet Aircraft". *J. Aviat. Med.* 27, 53, 1956.

"Cause of Hypoglycaemic Symptoms". *Lancet*, June 9 and June 23, 1016, 1956.

Malmejac, J. and Plane, P. "Influence of Oxygen Want on Functional Cortical Fitness". *J. Aviat Med.* 23, 177, 1952.

McQuarrie, I "Hypoglycemia in Infancy and Childhood". *Post-grad Med* 18, 287, 1955.

Mirsky, I. A "Role of Insulinase and Insulinase Inhibitors". *Metabolism* 5, 138, 1956.

PATERSON, J. L., HEYMAN, A., BATTEY, L. L. and FERGUSON, R. W. "Threshold of Response of Cerebral Vessels of Man to Increase in Blood Carbon Dioxide". *J. clin Invest* 34, 1857, 1955.

PINCUS, I J. and SNEDECOR, J. G. "Glucogen". *Metabolism* 5, 150, 1956

PORTIS, S A. "Life Situations, Emotions and Hyperinsulinism". *J Amer med Ass.* 142, 1281, 1950

POWELL, T. J "Unconscious Incidents while Flying". (Abstract). *J. Aviat. Med.* 27, 160, 1956.

RAKESTRAW, N. W "The Effect of Muscle Exercise on Certain Common Blood Constituents". *J biol Chem.* 47, 565, 1921.

SCHWARZ, W. "Untersuchen uber die verschiedenen arteriellen Blutruckreactionen bei Sauerstoffmangel". *Luftfahrtmedizin*, 1, 82, 1936.

SHARPEY-SCHAFER, E P. "Syncope" *Brit med. J* 4965, 506, 1956.

SHARPEY-SCHAFER, E. P., HOWARD, P, LEATHART, G. L and DORNHORST, A C "The 'Mess Trick' and the 'Fainting Lark'". *Brit med. J.* 382, 1951.

SPIEGEL, E A, HENRY, G C. and WYCIS, H. T "Changes of Cerebral Circulation Induced by Labyrinthine Stimulation". *Amer J. Physiol.* 142, 589, 1944.

STAVRAKY, G. W "The Effect of Oxygen on the Circulatory System in Conditions of Anoxia and Asphyxia". *Canad J Res* 23, 175, 1945.

TUTTLE, J. W., WILSON, M and DAUM, K "Effect of Altered Breakfast Habits on Physiologic Response". *J Appl. Physiol.* 1, 545, 1949

VAN WULFFTEN PALTHE, P M "Hyperventilatie en bloedsuikergehalte". *Aeromedica Acta* 2, 183, 1953.

SOME PRACTICAL MEDICAL ASPECTS OF ACCIDENT PREVENTION

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IN this paper I only intend to touch on those aspects of accident prevention which have a purely practical application, in our chosen field of Aviation Medicine and Physiology. Indeed, it would be pure presumption, on my part, to attempt to become over-scientific.

We, at SHAPE, are profoundly interested in the human factors, as a causative agent of aircraft accidents. Such accidents have a direct impact on recruiting and aircrew morale.

In addition, loss of life and of valuable and critical material becomes increasingly important, when looked at from the point of view of the complexity of the training of the modern aircrew, and the economics of modern aircraft and their weapon systems.

Much of this presentation may be "old news" but I want to stress, in particular, three things.

The first is "selection of aircrew" with special emphasis on certain aspects of fundamental research which still seems to be virgin ground, insofar as results go

Secondly, the essential and integral part that sound training in aviation medicine must play in any aircrew's career, and how we think this training should be carried out.

And, thirdly, the part we, at SHAPE, feel the Aeromedical Panel of AGARD play in helping SHAPE, and thus NATO, as a whole.

Perhaps, in accident prevention, we have the "raison d'être" for the existence of Aviation Medicine and Physiology as a recognized speciality, in the medical field. Everything we do and have done, is, and has been, directed at making the pilot and his crew, more comfortable, more efficient and more physiologically normal under all conditions of flight. We have done this by surrounding him with protective devices against unnatural elements, and all this effort has collectively and individually had a direct bearing on flying safety.

The danger, from our point of view, is, and always has been, that in our eagerness to protect the pilot, we overdo it and so saturate him with equipment, mental conundrums and advice, that we produce a reverse trend in efficiency and safety. What we have heard at this conference, during the sessions in Oslo, seems to confirm that we have already reached this point.

Modern flight and flight conditions, and the amount of knowledge aircrews have to absorb, have now rendered simplification of solutions to problems, an *absolute* must.

Where problems have been clear-cut, such as in anoxia, pressurization, effects of gravity and the development of the ejection seat, I think we can

However, in such fields as fear, fatigue and psychological selection, our efforts have not produced the answers for which we might have hoped.

And so to the first of the points which I wish to stress.

Selection of aircrew

In the selection of aircrew we are interested, to my mind, in two main things.

Firstly, that the man comes up to the physical standard required. This physical examination is, to a large extent, rule of thumb, relatively inflexible, and subject only to slight variation All our nations, by experience, have, generally speaking, much the same base line standard and we all see that this high standard of physical fitness is maintained by medical examinations

know for certain that·

I. He is temperamentally suited to flying, and

II. Even if he proves a sound peacetime pilot, he will stand up to the stress of flying, in war.

In my opinion, his instructor and later his fellow pilots, flight commander and squadron commander, in that order, will be the first to detect the "lack of guts" or "fire in the belly" under actual flying or war conditions

A good flight surgeon, by his close contact with his aircrew, may be able to detect the early signs of an incipient "crack-up" but generally speaking, it is the man's immediate superior who is the first to detect this.

If we can find a fool-proof selection procedure which eliminates the accident prone, the potential lack of moral fibre and the individual who is likely to allow fear to overcome his pride, we shall make an enormous contribution to the whole aircrew selection pattern, saving our countries large sums of money, through wasted training hours, and a lot of mental anguish to individuals who are unsuited to a flying career, but who cannot bring themselves to the point of publicly admitting it This facet of selection should also include the elimination of the man who is mentally unstable and unable to make full use of the initial and operational training facilities available to him, in other words the mentally incorrigibly lazy individual.

Fear is another problem We know very little about it, what is fear? Why does it affect individuals differently? Why is it infectious? What can be done about it? Is there any means of conditioning people to fear? And finally, can we find an easy solution to the problem of the diagnosis of fatigue? When does fatigue become dangerous?

I fully realize that a tremendous amount of work has been and still is being done investigating these problems but the results have so far been

subjects are receiving the time and attention they merit. I feel that work on these problems is still in the realm of fundamental research.

I repeat, that I have yet to see, in writing, any real evidence of success in this line.

This, of course, has nothing whatsoever to do with aptitude tests and the like. The Chairman, yesterday, suggested that we must not be retrospective. I don't altogether agree. I fully realize, expecially after yesterday's morning session, that this is a most complex problem, in fundamental research. The solution, however, must be simple.

Perhaps we may have to go back and employ electroencephalography, psycho-analysis and anything else the psychologist can dream up, on all those aircrew who have been grounded for fear, lack of moral fibre, proven accident proneness and see whether there is some simple factor common to all and unusual to those we term normal, i.e. liking blubber, or tripe, or disliking women.

I am convinced that this weeding out of such potential breakdowns is an economic survival and a wartime must in view of the operational requirement of getting the "A" weapons to the target.

The second point I wish to stress is the absolute necessity for full and sound indoctrination, in aviation medicine and aviation physiology, of all aircrews, *at all stages of their flying careers, as a fully authorized, recognized* and integral part of their ground training programme. We do not consider an aircrew fully trained unless he gets this indoctrination. *The responsibility for the official programme is the air staff's, and not the doctor's.*

During my travels around NATO, where there have been deficiencies in

hold the purse strings and the necessary power to make this training mandatory. Without this backing such training becomes *ad hoc*, sporadic and relatively useless.

This training must be given by experts. Nothing brings us into greater disrepute than for aircrews to be taught aviation medicine by doctors and physiologists who know less about the subject than those they are instructing.

We at SHAPE are convinced that this training requirement plays a vital part in the reduction of the accident rate.

To that end, SHAPE instigated, the Aeromedical Panel of AGARD *implemented, and MAS (Air)* in London finalized STANAG 3114, which laid down (and was accepted by all nations), the minimum training requirements for aircrews in the field of aviation medicine, during their training syllabus.

Recently, SHAPE developed a syllabus of training for the continuation training of operational crews, at regular intervals This has been forwarded to MAS (Air) for *national agreement, to be finalized,* as an addendum, to STANAG 3114. In this we have tried to highlight that group of physiological problems which it is convenient to call the "Killer Group".

of such centralization is that nations will be able to give their crews and their Air Force,

(I) The best possible training, utilizing their most experienced aviation medical instructors, with a degree of continuity unobtainable in any other way.

(II) A far greater range of training aids, at the least possible expense, by avoidance of duplication of such things as decompression chambers, ejection seat test rigs, etc : an important contribution to national economy.

(III) A concentration of Aviation Medicine training and research organizations under one roof

It should be noted that this concentration of training in no way takes the place of the flight surgeon, at base level, and his direct supervisory responsibilities.

By this means we consider that crews will be more fully aware of their physiological limitations, the aids they must use to overcome these deficiencies, and how these aids function and should be maintained.

Such training will make a major contribution to accident prevention.

I believe the Aeromedical Panel of AGARD, by exerting its influence, could be of great assistance, throughout NATO, in pushing this matter of centralization of training

As you all know, in many of our countries, establishing the importance of Aviation Medicine as a "must" in the minds of our "masters", the Air Staff, has been a difficult problem and perhaps for that reason, it has not received the priority it should have done, added to this, although we may be convinced, in our own minds, of physiological factors being the primary cause of an accident, proof is sometimes very difficult and often impossible, and this does not strengthen our hand with our Air Staffs.

However, during my visits around NATO, I have met with an encouraging and increasing awareness of the important part aviation medicine plays in an aircrew's career.

To sum up, we believe that centralization of aviation medicine training to be in the best possible interests of the pilot, the doctors and the nation, [illegible]

[illegible] her, the NATO Nations.

I realize that the Aeromedical Panel of AGARD is a research organization only and as such has strict terms of reference All right, but SHAPE is primarily interested in the practical aspects of aviation medicine particularly as it affects the aircrew, their effectiveness and accident prevention.

Now we all know that research is essential but research must be directed to a practical conclusion, and in this field, should not be entirely academic in its purpose

The Flight Surgeon on the spot is a practical man, dealing with practical problems, and is not really interested in how research is undertaken. However, he is vitally interested in the practical conclusions produced by Research He wants to know how it will affect the pilot Does it entail additions to his accoutrements already at saturation level and likely to constitute a hazard rather than a help?

Does it entail further complicating factors that the pilot has to add to the almost endless things he has to remember, and sp on? We feel the Aeromedical Panel of AGARD could advise us on such practical things (and I choose them at random). as:

(I) The value of the Ejection Seat Test Rig: its dangers, how these dangers can be prevented; how often is indoctrination required, if at all, etc.

(II) The use of the decompression chamber, how often, and how the best practical value can be obtained from practical demonstration.

(III) An evaluation of physical standards and requirements.

We, on your advice, could act as your executive mouthpiece, and forward such advice on an information basis, through the relevant MODs.

As I indicated, I have chosen the above, at random, rather as an illustration, than anything else.

In summary, gentlemen, it is still plainly evident that the military combat aircraft of today, and on the drawing boards for the future, are limited in their performance by the human factor—the men who must fly them. To increase man's ability to match the aerodynamic capabilities of the combat aeroplane, we have had to encase him in unnatural, uncomfortable apparatus, and then in a virtual capsule, which is dependent, for performance, on technical details. Then, with everything working perfectly, the pilot is able to take off into unnatural, lonely space above the earth. At this point, and for long periods of time on most occasions, he must keep constantly alert, keen of mind, with his reactions on the top line, to survive his enemies and/or accomplish his mission.

I submit that there is a far larger margin for error in the machine than in the man, for the success of such a flight. Yet our jet combat training pro-

trained and retrained again, and, in addition, be constantly indoctrinated

him to efficiently perform his mission or even allow him to return alive.

I suggest that this Aeromedical Panel and AGARD could make a great contribution to NATO by directing its thoughts, efforts and primary interests towards the improvements and developments which have a direct relation to the personal equipment, cockpit arrangements and conditions for the pilot, to improve his comfort and his efficiency to survive while flying his aeroplane to nearer its performance capabilities.

Finally, two points arising from the Conference:

(I) Plans, tactical, strategic and for interdiction, are based on getting the "A" weapon to the target.

We must never lose sight of that, and for that reason I should have liked to have heard more on these lines in protecting the pilot and less on get down or get out. Here, of course, we are up against peacetime requirements wanted by politicians and top brass alike, for political, propaganda and other reasons.

QUELQUES CAUSES AUXQUELLES ON PEUT IMPUTER LES ACCIDENTS AÉRIENS

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LA plupart des accidents d'aviation dépendent, comme vous le savez, du *facteur humain*.

Les statistiques les plus dignes de foi montrent que les accidents aériens sont dus dans une proportion supérieure à 65 pour cent à des erreurs des pilotes ou du personnel navigant ou du personnel à terre, qui a le devoir de contrôler l'efficience de l'avion ou l'allure de la navigation aérienne.

Les erreurs, en ce qui concerne le personnel navigant, peuvent dériver

I. d'une insuffisante aptitude physio-psychique au vol. Il s'agit en général de personnes qui n'ont pas passé à travers les épreuves rigoureuses d'une sélection médicale ou d'un contrôle sanitaire périodique,

II. d'un insuffisant entraînement au pilotage ou aux travaux de bord;

III. d'une insuffisante aptitude au pilotage,

IV. d'une résistance temporairement réduite par suite de maladies

d'anoxie et de dépression barométrique *in toto*, de l'aéroembolisme, des accélérations provoquées par les manoeuvres de vol, du mal de l'air, des variations de température, des vibrations, d'intoxications provoquées par le carburant ou par les gaz d'échappement des moteurs, etc.

Les facteurs mentionnés ci-dessus n'épuisent évidemment pas toutes les possibilités il faut en ajouter beaucoup d'autres que l'expérience peut mettre en évidence chaque jour.

Ma longue expérience de médecin d'aéronautique m'a amené à penser qu'une cause importante, dans la genèse des accidents aériens serait à rechercher dans l'hyperventilation non pas provoquée par l'anoxie (car, dans ce cas, cette dernière prendrait la première place comme cause efficiente), mais par d'autres causes, parmi lesquelles celle représentée par un état émotif prolongé. Une autre cause pourrait être recherchée, à mon avis, dans l'action de dérangement des bruits continus ou intermittents, même d'intensité médiocre.

Enfin l'on sait que les nuits blanches passées dans des divertissements plus ou moins épuisants, peuvent être la cause d'une réduction des énergies physio-psychiques, et, par consequent, d'accidents aériens.

En me basant sur ces considérations, j'ai chargé mes collaborateurs du Centre d'Études et Recherches de Médecine Aéronautique, que j'ai le honneur de diriger, d'exécuter quelques recherches expérimentales à ce sujet.

M.M. F. Rossanigo et M. Strollo se sont occupés en effet du premier problème, c'est-à-dire de l'influence de l'hyperventilation sur les temps de réaction.

Les variations des temps de réaction peuvent provoquer, comme on peut facilement le présumer, des erreurs de pilotage de l'avion ou dans la conduite de la navigation aérienne, et par conséquent, peuvent donner lieu à des accidents.

Nous avons voulu faire des expériences sur le phénomène pur de l'hyperventilation, c'est-à-dire sur une hyperventilation provoquée par la volonté et non déterminée par des raisons émotives ni par des médicaments, ni par l'inhalation de mélanges gazeux spéciaux, etc.

La technique expérimentale adoptée et les résultats obtenus sont les suivants.

Les recherches ont été faites sur 10 hommes sains, d'un âge moyen de 32 ans environ (de 20 à 48 ans), entraînés à respirer à travers la masque, et à régler et contrôler par la volonté leur respiration. Les expériences ont été exécutées le matin, après une période de repos d'une heure environ. Les sujets, assis, exécutaient l'épreuve des temps de réaction simple à 50 stimulations lumineuses, enregistrée à l'aide d'un appareil approprié. En même temps, on mesurait la ventilation pulmonaire à l'aide d'un spiromètre, on prélevait des échantillons d'air alvéolaire au moyen de l'appareil décrit par Rahn, et un échantillon de 5 ml. de sang veineux était recueilli en dehors du contact de l'air

Chaque sujet était ensuite invité à ventiler 70 pour cent environ en plus de sa ventilation pulmonaire à l'état de repos, précédemment déterminée et l'on contrôlait la quantité et la régularité de l'hyperventilation par le spiromètre, surveillé en même temps par l'expérimentateur.

Après quelques minutes, la valeur désirée était atteinte et maintenue, presque automatiquement, pour une période de 30 min

De la 20 ème à la 30 ème minute d'hyperventilation, on répétait l'épreuve des temps de réaction et les prélèvements d'air alvéolaire et de sang veineux, avec les précautions déjà mentionnées

A la fin de l'expérience le sujet répondait à un questionnaire concernant les troubles subjectifs observés pendant et immédiatement après l'hyperventilation

Les échantillons d'air alvéolaire ont été analysés à l'aide de l'appareil de Haldane-Margaria et après la composition pour cent on a calculé les tensions partielles des gaz alvéolaires. Le pH a été déterminé sur les deux échantillons de sang par la méthode potentiométrique, en employant le pH-mètre Beckman, à lecture directe et électrode à calomel. Les valeurs ainsi obtenues furent corrigées, en les rapportant à la température de 38°C.

Les valeurs sont données dans le *Tableau 1.* De la lecture de ce tableau, il apparaît ce qui suit

(I) On a obtenu une ventilation pulmonaire (V_{BTPS}) volontaire supérieure d'environ 67 pour cent à celle normale

(II) Pendant cette hyperventilation on a observé une diminution de 29 4 pour cent du $PA(co_2)$ et une augmentation de 13 pour cent du $PA(o_2)$ par rapport aux valeurs enregistrées avant les expériences, le pH subit une augmentation de 2·3 pour cent.

Tableau I Valeurs Moyennes des Variables Enregistrées Pendant les Expériences d'Hyperventilation Pulmonaire

	A	B	C	D	E	F	G	H	I	L	M	N
Variables	V_{BTPS}(l/min)		$PA(co_2)$(mm Hg)		$PA(o_2)$(mm Hg)		pH		*Temps de Réaction* (sec)			
									Valeur Moyenne		*Variation Moyenne*	
Condition	*Normal*	*Hyperv*	*Normal*	*Hyperv*	*Normal*	*Hyperv*	*Normal*	*Hyperv*	*Normal*	*Hyperv*	*Normal*	*Hyperv.*
Valeurs moyennes	8 098	13 511	38 74	27 35	102 55	115 91	7 28	7·45	170	200	20·4	34 9
Déviations standard	1 054	1 555	6 96	3 79	5 03	3 50	0 03	0·10	18	24	3 9	11 6
Différence pour cent		+67 0		−29 4		+13 0		+2 3		+ 17 6		+71

Les différences des moyennes des colonnes C et D, E et F, G et H, I et L, M et N sont toutes statistiquement significatives (t = 4·540, 6 897, 4 019, 3·162 *et* 3 756 *respectivement et pourtant* ($P <$ 1 *pour cent*).

(III) En même temps, on a constaté une prolongation de la valeur moyenne des temps de réaction, de +17·6 pour cent par rapport à la valeur moyenne normale, avec une variation de +71 pour cent.

Toutes ces variations ont été reconnues statistiquement significatives.

Du questionnaire présenté aux sujets, après chaque expérience, resultent les phénomènes suivants:

(a) Sensation de rigidité musculaire	(5 sur 10)
(b) Troubles de la vue	(5 sur 10)
(c) Sensation de fourmillement	(4 sur 10)
(d) Somnolence	(4 sur 10)
(e) Vertigo	(3 sur 10)
(f) Tremblement	(1 sur 10)
(g) Phénomènes vasomoteurs et sudation	(1 sur 10)

Un sujet, non compris dans les moyennes, manifesta une hyperventilation remarquable (plus de 32 l/min), en effet, sa ventilation au repos était déjà sensiblement supérieure à la normale. Les phénomènes objectifs et subjectifs observés chez ce sujet étaient de la même nature que ceux décrits ci-dessus; à cette différence près qu'ils se produisaient dans une plus grande mesure.

On peut donc conclure en affirmant que l'hyperventilation, au côté de l'acapnie et de l'alcalose, provoque un ralentissement des temps de réaction, représenté par une prolongation de la valeur moyenne, et des phénomènes secondaires variables qui peuvent être considérés comme des facteurs aggravants

M.M. M. Strollo et F. O. Debarnot se sont occupés de l'influence du bruit sur les temps de réaction.

Dix sujets sains, d'un âge moyen correspondant à 32 ans environ, dont les fonctions visuelle et acoustique étaient normales, ont été soumis à l'épreuve des temps de réaction simple, régulièrement enregistrés

Les mêmes sujets, dans les mêmes conditions de temps et de lieu, ont été soumis à une autre épreuve des temps de réaction simple, avec un casque en contact avec un magnétophone, reproduisant les bruits précédemmant enregistrés dans le cockpit d'un avion à réaction, moteurs et liaison radio en action.

Les résultats sont indiqués dans le *Tableau II*

Des valeurs obtenues il résulte que lorsque les sujets étaient soumis à l'action de perturbation du bruit, ils présentaient une remarquable prolongation de la durée des temps de réaction et une baisse de la régularité des réponses.

M. A. Scano a étudié la résistance à la dépression barométrique de sujets qui, avant de passer le test, avaient passé des nuits blanches en divertissements épuisants

Les données exposées dans le *Tableau III* ont été tirées par Scano d'un complexe de tests fonctionnels effectués du 8 juillet 1954 au 9 juillet 1956, sur 300 sujets sains, d'un âge moyen de 22 ans, étant tous des pilotes d'avions à réaction.

Ces sujets étaient soumis pendant la matinée à de nombreux tests fonctionnels pour l'évaluation de leur efficience respiratoire et cardio-circulatoire et de leur résistance à la dépression barométrique.

Le test de dépression barométrique consistait en une ascension fictive dans le caisson à dépression jusqu'à une altitude de 5500 m. Au niveau de la mer, à 3000 m et à 5500 m, on relevait la ventilation pulmonaire, la composition de l'air alvéolaire, la fréquence respiratoire, l'électrocardiogramme, la pression artérielle; les sujets étaient également soumis à une épreuve psychotechnique Ainsi ils demeuraient à l'altitude fictive de 5500 m pendant 30 min environ.

Tableau II Calculs Relatifs aux Temps de Réaction Simple Pendant l'Action de Perturbatrice du Bruit

Nom	Temps Moyen				Variation Moyenne			
	Normal		Bruit		Normal		Bruit	
	Valeur Brute (mill)	s^2	*Valeur Brute* (*mill*)	s^2	*Valeur Brute*	s^2	*Valeur Brute*	s^2
D F O	184	100	205	1	21·7	10 89	13	70 56
I D	161	169	194	100	15 1	10 89	16 6	23 04
F S	175	1	201	9	18 3	0 01	22	0 36
M G	189	225	220	256	20 8	5 76	23 4	4
S E	195	441	202	4	13 8	21 16	14	54 76
L A L	180	36	217	169	14	19 36	18 8	6 76
S M	145	551	197	49	13 5	20 01	33 6	148 84
L E	164	100	194	100	22 2	14 44	28 5	8 41
D B	161	169	190	196	13 8	21 16	17 5	12 21
G G P	190	256	224	400	20 7	5 29	26 7	84 49
	1744	2048	2044	1284	183 9	113 97	214 1	454 63
	$M = 174$		$M = 204$		$M = 18\ 4$		$M = 21\ 4$	
	$\sigma = 15$		$\sigma = 12$		$\sigma = 3\ 5$		$\sigma = 7\ 1$	
	$t = 17\ 2$				$t = 4\ 74$			

Dans un nombre de cas nullement négligeable, on a constaté qu'à cette altitude se produisaient des troubles d'une certaine importance: une profonde somnolence ou même la perte de la conscience, vertige et vomissement, de brèves périodes d'apnée.

Chez quelques sujets se manifestaient des altérations électrocardiographiques, caractéristiques de l'ischémie myocardique. L'inhalation d'oxygène a toujours éliminé de façon nette ces phénomènes.

Comme il semblait très étrange que tant de sujets sains et jeunes pussent présenter une telle réduction de leur résistance à une dépression barométrique de valeur moyenne, on en a recherché les causes. Il résulta alors, de

[illegible]

prendre le repos nécessaire.

C'est pourquoi on a jugé opportun de répéter le test après quelque temps, ayant préalablement recommandé aux sujets d'éviter toute intempérance pendant les jours précédant l'épreuve.

[illegible]

White, hypertension artérielle permanente, etc.), dans les épreuves successives, même répétées trois fois, manifestaient toujours le même comportement défaillant.

Il est donc vraisemblable que la plus ou moins grande résistance à la dépression barométrique dépend, outre que des particularités individuelles du fait que le sujet ait joui, ou non, d'assez de repos, du degré et de la nature des intempérances auxquelles le sujet s'est adonné avant la montée en altitude.

En concluant, on peut donc affirmer que

(I) L'hyperventilation peut provoquer un ralentissement des temps de réaction et des effets secondaires dus à l'alcalose résultante

(II) Les bruits provoquent également un ralentissement des temps de réaction et une moindre régularité des réponses.

(III) Le manque de repos physio-psychique convenable et l'épuisement des énergies du sujet, avant le vol, déterminent une diminution de la résistance à la dépression barométrique

Il est donc évident que de telles conditions peuvent provoquer des accidents aériens et peuvent aussi se trouver parmi les nombreuses causes des accidents inexplicables.

Résumé

Au Centre d'Études et Recherches de Médecine Aéronautique de Rome, on a exécuté des recherches expérimentales sur l'influence de l'hyperventilation sur les temps de réaction et sur l'influence des bruits, comme facteur de dérangement, sur les temps de réaction On a constaté qu'aussi bien l'hyperventilation que les bruits causent un ralentissement des temps de réaction et une moindre régularité des résponses. Une analyse critique des tests de résistance à la dépression barométrique, effectués sur 300 pilotes d'avions à réaction, a permis de constater une diminution de la résistance chez les sujets qui n'avaient pas reposé pendant la nuit précédant le test, et qui s'étaient adonnés à des déréglements Les mêmes sujets ayant, dans une autre occasion, bien reposé pendant la nuit avant de se présenter au test, avaient manifesté dans ce même test en caisson pneumatique, une résistance normale à la dépression barométrique.

Aussi est-il permis de déduire de ces considérations que l'hyperventilation,

Le test de dépression barométrique consistait en une ascension fictive dans le caisson à dépression jusqu'à une altitude de 5500 m Au niveau de la mer, à 3000 m et à 5500 m, on relevait la ventilation pulmonaire, la composition de l'air alvéolaire, la fréquence respiratoire, l'électrocardiogramme, la pression artérielle; les sujets étaient également soumis à une épreuve psychotechnique. Ainsi ils demeuraient à l'altitude fictive de 5500 m pendant 30 min environ.

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Dans un nombre de cas nullement négligeable, on a constaté qu'à cette altitude se produisaient des troubles d'une certaine importance: une profonde somnolence ou même la perte de la conscience, vertige et vomissement; de brèves périodes d'apnée.

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Comme il semblait très étrange que tant de sujets sains et jeunes pussent présenter une telle réduction de leur résistance à une dépression barométrique de valeur moyenne, on en a recherché les causes Il résulta alors, de

l'aveu même des intéressés, qu'ils avaient l'habitude de se rendre, les soirs précédant le jour des tests, dans des lieux d'amusements ou des restaurants caractéristiques, ils rentraient à l'hôtel très tard, étant ainsi empêchés de prendre le repos nécessaire.

C'est pourquoi on a jugé opportun de répéter le test après quelque temps, ayant préalablement recommandé aux sujets d'éviter toute intempérance pendant les jours précédant l'épreuve.

On a observé ainsi qu'une large partie des individus qui répétaient le test de résistance toléraient sans aucun trouble l'exposition à la dépression barométrique, se conduisant d'une façon tout à fait normale (*Tableau* III).

Au contraire, d'autres sujets, qui manifestaient déjà, au niveau de la mer, des altérations cardio-circulatoires de types différents (symptômes d'hypertrophie ou de lésion myocardique, syndrome de Wolff-Parkinson-White, hypertension artérielle permanente, etc.), dans les épreuves successives, même répétées trois fois, manifestaient toujours le même comportement défaillant.

Il est donc vraisemblable que la plus ou moins grande résistance à la dépression barométrique dépend, outre que des particularités individuelles du fait que le sujet ait joui, ou non, d'assez de repos, du degré et de la nature des intempérances auxquelles le sujet s'est adonné avant la montée en altitude.

En concluant, on peut donc affirmer que.

(I) L'hyperventilation peut provoquer un ralentissement des temps de réaction et des effets secondaires dus à l'alcalose résultante

(II) Les bruits provoquent egalement un ralentissement des temps de réaction et une moindre régularité des réponses

(III) Le manque de repos physio-psychique convenable et l'épuisement des énergies du sujet, avant le vol, déterminent une diminution de la résistance à la dépression barométrique.

Il est donc évident que de telles conditions peuvent provoquer des accidents aériens et peuvent aussi se trouver parmi les nombreuses causes des accidents inexplicables.

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Au Centre d'Études et Recherches de Médecine Aéronautique de Rome, on a exécuté des recherches expérimentales sur l'influence de l'hyperventilation sur les temps de réaction et sur l'influence des bruits, comme facteur de dérangement, sur les temps de réaction. On a constaté qu'aussi bien l'hyperventilation que les bruits causent un ralentissement des temps de réaction et une moindre régularité des résponses. Une analyse critique des tests de résistance à la dépression barométrique, effectués sur 300 pilotes d'avions à réaction, a permis de constater une diminution de la résistance

avaient manifesté dans ce même test en caisson pneumatique, une résistance normale à la dépression barométrique.

Aussi est-il permis de déduire de ces considérations que l'hyperventilation,

les bruits et la manque de repos sont des facteurs effectivement capables de réduire l'aptitude physio-psychique au vol, et qu'ils peuvent devenir par là des causes éventuelles de tous ces accidents de vol qu'un premier examen ferait paraître inexplicables.

SUMMARY

Some experimental researches were carried out, at the Centre of Studies and Researches in Aviation Medicine in Rome, concerning the influence of hyperventilation on reaction times and the influence of noise, as a disturbing factor, on reaction times. It was possible to observe that both hyperventilation and noise cause a delay in the reaction time and an impairment in the uniformity of the subject's responses.

An analytical review of the results of about 300 tests of resistance to barometric depression, carried out on jet pilots, resulted in the observation of a decreased resistance of those subjects who spent the night before the test without sleeping and in exhausting amusements. The same subjects, tested for a second time after a night of rest, showed in the same conditions of barometric depression (in the depression chamber) a normal resistance.

It is possible to infer, from these findings, that hyperventilation, noise and the lack of rest represent some factors able to impair the physio-psychic efficiency during flight. They could therefore be some possible causes of unclassified flight accidents.

Remarques	*Points Totaux*
Le sujet n'avait pas reposé pendant une grande partie de la nuit précédant l'épreuve	47/100
Le sujet a présenté une légere somnolence	60/100
Désordres alimentaires dans le jour précédant l'épreuve Le sujet a présenté de la somnolence à 5500 m et au terme de sa permanence à grande altitude, du vomissement Albuminurie dosable avant et après l'épreuve	24/100
N'a pas présenté de troubles manifestes en dépression barométrique	75/100
Le sujet n'avait pas reposé pendant une grande partie de la nuit précédant l'épreuve, et pendant celle-ci il a présenté, à la 4 ème minute, une breve apnée et perte de conscience On a dû administrer O_2	46/100
Pas de troubles manifestes en dépression barométrique	83/100
Le sujet n'avait pas reposé pendant une grande partie de la nuit précédant l'épreuve, pendant celle-ci, il a présenté une somnolence remarquable et vomissement à 5500 m	48/100
N'a pas présenté de troubles manifestes en dépression barométrique	84/100
Le sujet a une brève défaillance apres 10 min environ de séjour à 5500 m On a dû administrer O_2	45/100
N'a pas présenté de troubles manifestes en dépression barométrique	74/100
Le sujet n'avait pas reposé pendant une grande partie de la nuit précédant l'épreuve. Après quelques minutes de séjour à 5500 m il a présenté perte de conscience, on a dû administrer O_2	49/100
N'as pas présenté de troubles manifestes en dépression barométrique	82/100
Des désordres alimentaires ont eu lieu les jours précédant l'épreuve Pendant celle-ci, a présenté étourdissement, vertiges, céphalalgie, un soudain et violent stimulus à la miction	49/100
N'a pas présenté de troubles manifestes en dépression barométrique	88/100

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LE CLIGNEMENT DES YEUX, CAUSE POSSIBLE D'ACCIDENTS AÉRIENS

E. Evrard

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Parmi les causes les plus fréquentes d'accidents aériens, où le facteur humain peut être mis en cause, on peut ranger les accidents d'atterrissage et les collisions en vol. Les avions à hautes performances actuellement en service présentent en général des vitesses d'atterrissage élevées (250 à 300 km/hr). La précision, exigée du pilote pour la correction de l'atterrissage, repose totalement, jusqu'à présent, sur l'emploi continu et correct du sens visuel pendant toutes les manoeuvres de l'approche et de l'atterrissage lui-même. Il en est de même pour le vol en formation ou l'évitement d'un avion. Le clignement involontaire des yeux engendre une période aveugle. Il est donc légitime de se demander, en raison des distances parcourues par certains types d'avions durant cette période, si le clignement peut intervenir dans la genèse de certains accidents aériens dont l'explication n'a pu être fournie.

Le Problème

Le "black-out" ou période aveugle qui accompagne le clignement involontaire présente en durée des variations assez grandes Poulton[1] citant les travaux de Lawson[2], lui attribue une *durée* moyenne de 0·25 sec. En outre, chez 70 pour cent environ des sujets, le clignement est suivi d'une période de "vision mobile" qui est causée par une rotation des globes oculaires concomitante au clignement Ces sujets ont donc, à chaque clignement des yeux, une période estimée en moyenne par Poulton à 0·55 sec, où l'utilisation de la vision est impossible pour fournir les informations visuelles nécessaires à l'accomplissement de la tâche. *Le nombre* de clignements par minute est extrêmement variable. Pour Lawson, chez plus de 80

menter sous l'effet d'une tension psychique intense, de la fatigue et de la peur. Elle peut être fortement réduite dans les moments de concentration visuelle ou mentale intense. Sur ces données, Lawson a prétendu qu'une fréquence excessive de clignements pouvait causer une propension aux accidents aériens, en facilitant les possibilités d'erreur dans l'évaluation rapide d'événements visuellement observés et de courte durée.

En fait, la durée d'absence des sensations visuelles, à l'occasion d'un clignement, s'établit comme suit pour les vitesses, actuellement utilisées au cours de la phase finale de l'approche·

Vitesse	*Espace parcouru durant 0 55 sec*
180 km/hr	26 m
200 ,,	29 ,,
240 ,,	35 ,,
260 ,,	38 ,,
300 ,,	43 ,,

La littérature sur les relations entre le clignement réflexe et le genre d'activité auquel se livre un sujet est extrêmement abondante. DREW[4] en a fait récemment (1950) un excellent résumé, Malheureusement, les conclusions des différents expérimentateurs sont souvent contradictoires. Ces désaccords sont généralement dus à la nature différente des tâches qui ont servi à mesurer le niveau de la performance accomplie pendant le clignement.

L'activité qui nous intéresse dans cette étude est uniquement le pilotage d'un avion, tâche de nature sensori-motrice, réclamant particulièrement dans certains moments délicats du vol, un degré prolongé de vigilance visuelle, sans modification soudaine de la fixation visuelle. Nous nous sommes proposé de vérifier expérimentalement l'exactitude de certaines données objectives importantes relatives au clignement pendant l'accomplissement d'une tâche de même nature que le pilotage. Sur cette base, nous envisageons ensuite de discuter le rôle éventuel du clignement comme cause possible d'accident aérien.

OBSERVATIONS SUR LE CLIGNEMENT INVOLONTAIRE PENDANT CERTAINES TÂCHES SENSORI-MOTRICES ANALOGUES AU PILOTAGE

Nous avons examiné la fréquence du clignement durant l'accomplissement de certaines tâches sensori-motrices complexes, exigeant une vigilance constante pendant leur exécution. Ce sont:

(I) le test de coordination dans la carlingue MSA de la RAF,
(II) le stipple-test ou test de Bourdon-Wiersma.

Test de coordination dans la carlingue MSA de la RAF

Cinquante candidats élèves pilotes ont été soumis au test de coordination des 4 membres dans la carlingue MSA, utilisée à la RAF. L'épreuve, qui dure 90 sec, consiste dans la fixation d'un spot lumineux mobile, et son maintien dans une zone centrale de l'écran au moyen d'un stick et d'un palonnier. Des sources visuelles de distraction sont présentées pendant l'exécution de la tâche. Les sujets ignoraient que le nombre de clignements serait enregistré au cours de l'épreuve par un observateur, occupant une position latérale oblique par rapport á l'appareil

Les résultats s'établissent comme suit:

32 sujets (64 pour cent) n'ont pas cligné durant les 15 premières sec
21 sujets (42 pour cent) ,, ,, ,, 30 ,, ,,
13 sujets (26 pour cent) ,, ,, ,, 45 ,, ,,
8 sujets (16 pour cent) ,, ,, ,, 60 ,, ,,
5 sujets (10 pour cent) ,, ,, ,, 75 ,, ,,
2 sujets (4 pour cent) ,, ,, ,, 90 ,, ,,

Il fut également observé que la fréquence des clignements augmente pour chaque période successive de 15 sec.

Ces résultats peuvent être rapprochés des observations rapportées par ELLIS et ALLAN[5] qui ont étudié le mouvement des yeux de 11 pilotes de Météor durant l'approche visuelle et l'atterrissage. Chaque vol a consisté en 3 circuits avec atterrissage En filmant l'image de la face réfléchie par un miroir bien placé dans le cockpit, ils ont noté, entre autres choses, la fréquence du clignement durant ces activités Ils ont trouvé que cette dernière est grandement réduite chez tous les sujets. Le clignement est entièrement absent chez 7 d'entre eux (63 6 pour cent) durant les 30 sec qui précèdent immédiatement l'atterrissage; 2 n'ont eu qu'un clignement; 2 ont eu 2 clignements

Test de Bourdon-Wiersma (stipple-test)

Le test de Bourdon-Wiersma ou stipple-test a été administré à 449 candidats élèves pilotes selon la technique décrite par VAN WULFFTE PALTHE[6]. Le nombre de clignements et le moment de leur apparition ont été notés Les sujets n'ont jamais eu connaissance que leurs clignements étaient enregistrés. L'épreuve consiste à barrer des signes, constitués de points, répartis sur 50 lignes. Elle dure en moyenne 10 min Elle dépasse rarement 12 min

La moyenne arithmétique du nombre de clignements pour toute la durée de l'épreuve a été de 22 93.

Par tranche de 10 lignes, c-à-d par cinquième de l'épreuve, ce qui correspond en durée à une période approximative de 2 min, les moyennes arithmétiques du nombre de clignements s'établissent comme suit

1e tranche	de	10	lignes	1 38	clignements
2e	,,	10	,,	3 34	,,
3e	,,	10	,,	5·30	,,
4e	,,	10	,,	6 30	,,
5e	,,	10	,,	6 61	,,

Dans l'interprétation du test, nous avons, au cours d'une étude précédente, classé les sujets d'après la durée l'épreuve, le temps, le nombre de fautes et [illegible] fournit le classement des sujets, en pour cent par catégorie, selon le nombre total de clignements durant l'épreuve.

Nombre de clignements pendant l'épreuve	*Pour cent des sujets* ($N = 404$)				
	N $n = 262$	E $n = 57$	C $n = 27$	F $n = 55$	H $n = 3$
25 et—	76 33	50 88	62 96	78 18	pour mémoire
26 à 50	18 32	29 82	22 22	18 18	
51 à 75	3 05	12 28	3 70	1 82	
76 à 100	1 53	3 51	0	1 82	
101 à 125	0 38	1 75	7 40	0	
126 et plus	0 38	1 75	3 70	0	

L'expérience permet les constatations suivantes:

(I) Bien que le degré d'attention exigé soit exactement le même pendant toute l'épreuve, la fréquence du clignement qui est très faible pendant les 2 premières minutes, augmente à mesure que l'épreuve se poursuit. Cette augmentation devient cependant très réduite, voire insignifiante, à partir de la 9e min.

(II) Les sujets des catégories E et C, c-à-d ceux montrant une fluctuation considérable de l'attention, mise en évidence par la grande dispersion des temps nécessités pour le travail, ligne par ligne, sont également ceux qui présentent la fréquence la plus importante de clignements au-delà de 25 et surtout au-delà de 50 pour la durée totale de l'épreuve.

(III) La fréquence de clignements est la plus faible au début de la tâche; elle augmente ensuite graduellement, puis tend vers un niveau à peu près constant. Ce plateau correspond à une fréquence beaucoup plus basse que celle citée pour des situations normales n'exigeant pas d'attention soutenue.

Ces constatations rejoignent celles que DREW[4] puis POULTON et GREGORY[8] avaient eux aussi remarquées au cours d'expériences assez similaires: celles-ci consistaient essentiellement dans l'accomplissement d'une tâche sensori-motrice où le sujet devait suivre, au moyen d'un pointeau manoeuvré par un mécanisme bimanuel, un tracé d'abord régulier, puis irrégulier.

(IV) Le nombre de clignements n'est pas toujours en rapport avec un relâchement de l'attention ou une fluctuation de l'état de conscience. En effet, des sujets ayant de nombreux clignements pendant l'exécution du test de Bourdon-Wiersma, ont cependant d'excellents résultats globaux à ce test. On ne peut d'ailleurs oublier que certains facteurs tels que l'irritation de la cornée ou de la conjonctive, la dessication relative de la cornée ou de la conjonctive, provoquent le réflexe du clignement et peuvent accroître sa fréquence sans l'intervention de conditions psychiques particulières.

(V) Afin d'obtenir éventuellement des déductions pratiques pour la sélection des candidats pilotes, nous avons examiné si les sujets ayant plus [illegible] cès leur [illegible] x ayant [illegible] l'heure présente, beaucoup trop restreint pour pouvoir en tirer des déductions valables. En effet, sur un lot de 27 sujets, 13 sont devenus pilotes, dont 2 avaient plus de 50 clignements (67 et 79). Quatorze ont été éliminés pour inaptitude prof [illegible]

Une autre se [illegible] mentaire. Sur [illegible] 5 avaient plus de 60 clignements. Sur 50 ayant échoué, 6 avaient plus de 50 clignements. Au surplus la possibilité de l'intervention de conditions physiologiques ou pathologiques passagères, localisées uniquement à la conjonctive et à la cornée, telles que celles énumérées plus haut, empêchent tout essai d'interprétation valide, à base purement psychique, chez les sujets présentant une fréquence anormale de clignements durant les tests.

SIGNIFICATION DU CLIGNEMENT COMME CAUSE POSSIBLE D'ACCIDENT D'AVION

DREW, puis POULTON et GREGORY[8] ont montré expérimentalement que les

clignements étaient parfois suivis d'une détérioration de la performance dans l'accomplissement d'une tâche sensori-motrice

Faut-il de là déduire que dans certains cas le clignement pourrait être une cause d'accident aérien? Une conclusion ne peut être formulée qu'après examen de divers points

(I) Quelle est la fréquence des interruptions du mécanisme sensoriel captant les informations visuelles nécessaires aux phases de vol considérées?

(II) Existe-t-il des mécanismes de suppléance ou de compensation?

(III) Quel est l'ordre d'importance qu'occupe l'imperfection de l'instrument sensori-moteur causée par le clignement, parmi les autres imperfections ou défauts impliquant le facteur humain?

(I) Quelle est la fréquence des clignements durant la phase finale de l'approche ou durant des phases de vol nécessitant un degré de vigilance pour l'accomplissement des manoeuvres avec contrôle visuel constant?

Les observations faites en vol par Ellis et Allan[5] concordent avec les résultats de nos expériences faites en laboratoire et avec celles de Drew[4] et de Poulton et Gregory[8], faites également en laboratoire. le nombre de clignements est très réduit dans ces circonstances. Nos expériences n'ont pas dépassé une durée de 12 min pour la période de vigilance continue, de degré élevé, durant laquelle s'effectue la tâche sensori-motrice. Toutefois, il est rare qu'en vol on rencontre des circonstances exigeant des périodes aussi longues de vigilance extrême, sans périodes de détente si courtes soient-elles On peut donc admettre que le clignement est très peu fréquent durant les moments critiques d'un vol. Même après une période d'attention soutenue de 10 min, sa fréquence dépassera rarement, chez la plupart des sujets, 4 clignements/min pendant l'exécution de la partie difficile d'une tâche

(II) Si le clignement se produit à un moment critique pour le contrôle de l'avion, quel sera l'effet de détérioration de la tâche motrice? Existe-t-il des mécanismes de suppléance ou de compensation?

Bartlett[9] et Poulton[1] ont bien montré que l'estimation des effets des clignements sur l'exécution d'une tâche sensori-motrice exigeant rapidité et précision doit faire nécessairement intervenir le phénomène d'*anticipation* sous ses deux formes· l'anticipation au niveau de l'organe sensoriel de réception et de captation du stimulus visuel (anticipation du récepteur sensoriel) et l'anticipation au stade de la perception (anticipation de perception). Dans l'anticipation du récepteur sensoriel, le sujet a la vision anticipée du signal visuel ou de la situation à laquelle il devra répondre. Dans l'anticipation de perception, le sujet a une connaissance anticipée du signal visuel à venir, grâce à son expérience antérieure de telles situations Dans les deux formes d'anticipation, le sujet peut donc préparer sa réponse en vue de son exécution correcte au moment opportun. L'anticipation peut-elle jouer un rôle compensateur suffisant pour assurer au moment opportun le geste moteur qui contrôlera ou stabilisera l'avion malgré la lacune visuelle due au clignement?

Pratiquement, le problème du pilotage de l'avion pendant le clignement se présente sous un des deux aspects suivants

(a) Le pilote se trouve placé brusquement devant des circonstances

absolument imprévues, dans une phase critique du vol, exigeant une action immédiate sur les commandes. Aucune anticipation n'est donc possible. Si, dans cette situation, se produit un clignement, la période d'absence de réception du stimulus visuel (0·55 sec) devra être ajoutée au temps de réaction psycho-motrice avant de pouvoir obtenir un début de réponse motrice destinée au contrôle ou à la stabilisation de l'avion. A supposer que le temps de réaction psycho-motrice soit de 0·30 sec, un délai de 0 85 sec s'écoulera avant l'amorce de la réponse motrice sur les commandes. Il est évident que le retard dans l'exécution de la performance, imputable au clignement, peut dans ces circonstances être cause d'accident.

(b) *L'anticipation intervient. Ce sera le cas dans le plupart des circonstances* du vol. Le problème consiste alors à déterminer dans quelle mesure le pilote pourra éviter les effets possibles de la période aveugle due au clignement. Comme le plus souvent, il s'agit d'anticipation de réception sensorielle, le pilote pourra préparer sa réponse motrice. Celle-ci ne subira aucune répercussion si un clignement survient au moment de son exécution. S'il s'agit d'une anticipation de perception, le pilote peut répondre selon son estimation de la situation pendant la période aveugle et indécise du clignement Il doit donc anticiper pour cette période (0·55 sec) et pour la durée du temps de réaction psycho-motrice.

Dans ces circonstances, le pilote sera donc capable de compenser l'absence temporaire d'informations grâce à l'anticipation.

(III) Puisque le clignement ne peut être exclu comme cause possible d'accident, en cas de coïncidence où l'apparition d'événements imprévus exige une réponse motrice immédiate, il importe d'examiner l'ordre d'importance de ce facteur parmi les autres facteurs humains auxquels on impute généralement les accidents inexpliqués.

(a) *L'absence d'information visuelle due au clignement est de courte durée,* puisqu'elle dépasse rarement 0·55 sec. La lacune purement physiologique dans l'information visuelle est bien plus longue dans beaucoup de circonstances où n'intervient pas le clignement: par exemple, lorsque le pilote passe de la vision de ses instruments à celle de ses repères extérieurs, au sol, et vice-versa. Ce mécanisme se reproduit de nombreuses fois pendant l'approche. ALLAN et ELLIS[5] ont trouvé que pendant l'approche *visuelle,* 12 pour cent du temps étaient consacrés au déplacement du regard de l'extérieur vers le tableau de bord et vice versa. Cette période, inutilisée pour l'information visuelle, est beaucoup plus longue que celle imputable aux clignements

(b) On a attribué à la fatique un rôle important dans l'augmentation de [illegible]

[illegible] conjectures. Il semble [illegible] de la fréquence [illegible] asse rarement 4 clignements/min à la période finale du test. Il semble donc plus logique de considérer *la fatigue elle-même* comme un facteur plus important de détérioration de performance et par conséquent comme cause d'accident, que le clignement associé à cette fatigue.

(c) POULTON et GREGORY[8] considèrent le clignement comme un signe de vigilance réduite. Il semble résulter de nos observations au cours de stipple-test (voir tableau des fréquences de clignement en fonction des types de réponse au stipple-test) que ce soit chez les sujets montrant des fluctuations continuelles et importantes de l'état de vigilance (types E et C) que la

beaucoup plus importants de l'insuffisance de l'état de vigilance: mais c'est ce dernier état qui détermine l'inaptitude au vol. En conclusion, il est impossible d'exclure totalement le clignement comme cause possible d'accident dans l'accomplissement d'une tâche telle que le pilotage, basée sur la permanence des informations visuelles Cependant, malgré l'accroissement des vitesses d'atterrissage et des vitesses de vol, ce facteur ne peut pratiquement jouer que dans des circonstances où toute anticipation est absente. Ces circonstances ne sont pas usuelles en vol. Parmi les hypothèses à envisager pour tenter de donner une cause plausible aux accidents inexpliqués, ce facteur doit être rangé loin apres la fatigue et après l'inattention ou la fluctuation de l'attention dont il pourrait bien n'être qu'un simple signe précoce

SUMMARY

The problem is to ascertain whether blind periods caused by involuntary blinking could cause accidents owing to the great distances travelled in very brief intervals by modern aircraft

(used in the RAF) The results show that 64 per cent of all the subjects did not blink for

The

shows a

the cornea, of the conjunctiva, etc) can affect blinking frequency in the absence of special psychological influences.

One can assume that in flight, blinking takes place very seldom during critical phases (as in approach for instance). Anticipation of both types (receptor anticipation and perceptual anticipation) compensates sufficiently for the temporary lack of information caused by a blind period, these blind periods seldom exceed 55 sec;

in the deterioration of performance blinking due to fatigue plays a lesser role than fatigue itself.

In conclusion, although it is not possible to discard blinking entirely as a possible cause of accidents, it is a factor that can play a role only in very unusual circumstances, when anticipation is lacking. Blinking is only a minor and practically negligible limitation.

References

1 Poulton, E. C. "Lawson's Disregard of Anticipation in Discussing the Effects of Blinking in Sensory-motor Skills". Flying Personnel Research Committee No 742, Air Ministry, October 1950

2 Lawson, R. W. "Blinking. Its Role in Physical Measurement". *Nature*, Lond. **161**, 154, 1948.

3 Duke-Elder, W. S. *Text-book of Ophthalmology*. Kimpton, Londres, 1942.

4 Drew, G. C. "Variations in Reflex Blink Rate During Visual-Motor Tasks". Flying Personnel Research Committee No. 749, Air Ministry, December, 1950.

5 Ellis W. H. B. et Allan, R. M. "Pilots Eye Movements During Visual Approaches and Landings". Flying Personnel Research Committee No 888, Air Ministry, September 1954.

6 van Wulfften Palthe "Medical Tests for Detecting Latent Epilepsia and Fluctuations in the Level of Consciousness". Collected papers on Aviation Medicine, AGARDograph No. 6, 1955.

7 E[illegible] à la

8 Pc[illegible]

9 B[illegible] Flying Personnel Research Committee No. 765, Air Ministry, 1951).

SPATIAL DISORIENTATION IN OPERATIONAL FLIGHT

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THE problems in aerial equilibration or spatial orientation [illegible] student aviator are [illegible] CLARK, *et al* 1954) [illegible] cause factor in flyir [illegible]

[illegible]

requirements for maintaining spatial orientation, then he [illegible] immune to accidents involving "pilot's vertigo". Since [illegible] pilots should be assigned to operational units, such [illegible]

[illegible]

tion, training and proficiency maintenance are inade[illegible] instrumental means of maintaining orientation in fligh[illegible] requirements under all circumstances In order to arrive [illegible] regarding the significance of disorientation as an accide[illegible] factor among experienced pilots, this study was [illegible] information regarding types and seriousness of "vertigo" [illegible] are encountered by pilots in overseas operational units

PROCEDURE

This study consists of the following three sub-tasks: (1 [illegible]

of pilot disorientation experiences, (II) labyrinthine sensitivity testing of "vertigo susceptible" and "vertigo non-susceptible" pilots, and (III) review of types and incidence of "pilot's vertigo" accidents in operational units.

Experiences of disorientation in flight were collected in conjunction with a survey of altitude reactions and incidents. This survey was conducted at a physiological indoctrination centre which is responsible for the refresher physiological training of all aircrew personnel in the major overseas command of United States Air Forces in Europe. Aircrew of high-performance aircraft are required to undergo refresher physiological training every eighteen months at this centre. The survey was conducted during attendance of this scheduled refresher training. The disorientation study was limited to pilots. These pilots are assigned to tactical units throughout the USAFE command. Most of these units are fighter bomber and fighter interceptor type although other types such as light bombardment, tactical reconnaissance and combat cargo were represented. The types of aircraft used by these units are predominantly F84G, F84F, F86F, F86D, F86H, B45, B57, RB57, T33 and C119.

A write-in questionnaire was used which requested specific information regarding the following topics.

(I) Hypoxia incidents
(II) Hyperventilation
(III) Decompression Sickness
(IV) Disorientation in Flight (Vertigo)
(V) Explosive or Rapid Decompression
(VI) Personal Equipment Problems

The information requested concerning disorientation included the following·

(I) Frequency
(II) Symptoms and severity
(III) Flight conditions (night, weather, single flight, formation in weather etc)
(IV) Effect on control of aircraft
(V) Circumstances of recovery

[illegible] etc)

[illegible]

data from the questionnaires would remain strictly confidential and no signatures were required

In conjunction with the survey it was decided also to conduct a comparative study of the non-auditory labyrinthine sensitivity of *pilots with an* apparent high susceptibility to "vertigo" and pilots with an apparent non-susceptibility as indicated by the questionnaire results Individuals of high and low "vertigo" susceptibility were selected from random groups of pilots attending the refresher training. They were subjected to a standard Barany rotation chair test Five tests were conducted on each pilot: (I) right rotation, 10 times in 20 sec, head flexed 30° forward, (II) left rotation, 10 times in 20 sec, head flexed 30° forward, (III) right rotation 5 times in 10 sec, face rotated to left and sagittal plane of head in the horizontal position, (IV) left rotation 5 times in 10 sec, face rotated to right and sagittal plane of head in

the horizontal position, (V) coriolis acceleration produced by oscillation of head from forward flexed position to moderately rearward extended position every 10 sec for 4 oscillations during constant rotation to right at the rate of one rotation every 2 sec. The total period of exposure during the 4 oscillations was 50 sec. Labyrinthine sensitivity was based upon duration of after-nystagmus The fifth test was used to determine central and autonomic nervous system sensitivity to labyrinthine stimulation as indicated by pallor, sweating, nausea, vomiting and change in bood pressure.

One important aspect of conducting the Barany tests was the stimulation

flying.

A review of major aircraft accidents in the USAFE Command during the past two calendar years was accomplished. All accidents attributed to "pilot's vertigo" were reviewed and abstracts of typical "vertigo" accidents were obtained for inclusion in this study.

Subjects: The questionnaire was administered to 685 rated pilots assigned to operational units. No attempt was made to restrict the study to an homogeneous population, however, the majority of subjects were jet fighter pilots. The average total flying experience of these pilots was approximately 1625 hr, and the average jet experience was approximately 450 hr All the subjects (excluding controls) who were submitted to labyrinthine tests were jet pilots.

Results

Questionnaire survey of disorientation experiences

"Pilot's vertigo" is a condition universally experienced by all pilots. The questionnaire survey revealed that many pilots recorded no "vertigo" experiences, however when questioned directly these pilots would admit having had some sensory illusion of flight on one or more occasions Repeated questioning of pilots who claimed no disorientation experiences failed to reveal one pilot who had never experienced "vertigo" in flight The results of the questionnaire survey with regard to incidence of serious disorientation incidents are indicated in *Table I.*

Table I Spatial Disorientation Experiences in 685 Pilots

Degree	*Mild*	*Moderate*	*Severe*
Number of jet pilots	324	125	29
Number of non-jet pilots	184	20	3
Total	508	145	32

This tabulation indicated the numbers of pilots recording mild, moderate

and severe "vertigo" experiences at some time in their career. *Mild experiences* include those which do not significantly affect the pilots flight performance to a noticeable degree and do not create a mental hazard. *Moderate experiences* include those which adversely affect the pilots flying ability to a noticeable degree and produce moderate mental stress. *Severe experiences* include those which produce severe mental stress and usually result in complete loss of control of the aircraft. Approximately 75 per [illegible]

ences recorded one or more of these. Extracts of 57 typical moderate and severe types of disorientation experiences were reported at the meeting.

These recorded experiences reveal "vertigo" incidents occurring under all types of circumstances. However, the overwhelming importance of weather formation in operational flying as a cause of disorientation in experienced pilots is indicated in a large number of these reported incidents. This does not mean that single-ship instrument flight ceases to be a problem area for operational units. This fact is indicated by a number of these recorded experiences. The co-ordination difficulties and time delay involved in transitioning from formation reference to instrument reference are illustrated in the recorded experiences of many of the pilots. This large group of "vertigo" incidents falls into the category of illusions of attitude and motion. *Almost 100 per cent of the recorded experiences were of this type.* Only a few visual illusions such as confusion of lights with stars, illusions of relative motion and autokinesis were recorded. These comprise a very small secondary group of unusual types of disorientation experiences.

Some of the unusual features of the latter "vertigo" experiences in comparison with the previous group include the fact that visual illusions [illegible] night

occurs under daylight weather conditions. Disturbing effects of head movements during aircraft movements also occur, some of these effects being probably the result of coriolis acceleration. The disturbing effects of passing through cloud layers has been mentioned by several pilots in discussions. Rarely, cases of true vertigo have been reported to result from the effects of acute aero-otitis media and the unusual pressure changes in the middle ear may possibly affect the function of the non-auditory labyrinth in some individuals.

[illegible] importance [illegible] in the [illegible] able II. [illegible] flight condition was most fre- [illegible] ional [illegible] ation flying after assignment to operational units.

Table II Flight Conditions and Frequency of Disorientation

Flight Condition	*Number of Times Recorded*
Not stated	331
[illegible]	211
[illegible]	119
[illegible]	69
[illegible]	58
[illegible]	42
[illegible]	36
[illegible]	22
[illegible]	21
Single ship penetration turn	16
Hood	15
Formation (wing position) to instruments	*11*
GCA	6
Northern lights	6
Cloud layers	5
Night Climb-outs	5
IFR to VFR	3
Low level over water	2
Other Contributing Factors	
Head movements during manoeuvre	10
Head cold with "plugged ears"	8
Period of "lay off"	5
Fatigue	4
Hangover	3
Instrument failure	2
Air sickness	1
Radio difficulty	1
"Psychological difficulty"	1

Table III Pilots Recommendations

	Number of Times Recorded
None	265
Cannot be prevented, ignore	121
[illegible]	117
[illegible]	45
[illegible]	23
[illegible]	19
[illegible]	16
[illegible]	16
Instrument cross checking when formation flying	15
Relax	14
[illegible]	10
[illegible]	9
[illegible]	9
[illegible]	8
[illegible]	8
Stay on instruments when in broken clouds	7
Do a known manoeuvre, check and reorient	3
Check gauges before departing formation	3
Close eyes or look away from instruments momentarily	2

It was considered that perhaps some useful information would result from opinions of pilots concerning means of overcoming or preventing adverse effects of disorientation. *Table III* presents recommendations of the surveyed pilots in this regard.

The above tabulated results appear to indicate that the majority of pilots considered that either no problem exists or that if "vertigo" is a problem there is little one can do about it. Of those who apparently considered "pilot's vertigo" to be a problem the majority believed that practice and training are the essential means of attacking the problem.

It is of interest that a number of pilots felt the need of additional indoctrination in the mechanisms and physiology of disorientation. In discussions with these pilots, following refresher physiological training, it was evident that our demonstrations of reversal of labyrinthine sensations in the Barany chair were most convincing and that it was their first exposure to this type of indoctrination. While the concept of complete unreliability of labyrinthine and other proprioceptive sensations is readily acceptable, it is apparent that a convincing demonstration is of value in stimulating the pilot to adopt a more resolute attitude toward learning to ignore and suppress these sensations. Such demonstrations may therefore result in increased training effort by the individual with respect to attitude instrument flying proficiency.

Labyrinthine sensitivity tests

The procedures used in these tests are described above. During a period of approximately 4 months, in the course of the questionnaire survey, two groups of pilots were selected for testing on the basis of recorded "vertigo" exper-

personnel, of appropriate age distribution, was also tested.

Table IV Labyrinthine Sensitivity

	Non-flyer Controls (30)	*Vertigo Susceptible* (30)	*Vertigo Non-susceptible* (30)
Total flying time	—	1354	1765
Jet time (hr)	—	581	578
After-nystagmus—H≡Horizontal (sec)	18 4	18 5	18 1
After-nystagmus—V≡Vertical (sec)	11 9	12 0	13 0
B P change (systolic) (mm Hg)	−3 3	−7 3	−2
Unable to complete 4 coriolis	5	8	0
Total autonomic symptoms	30	29	11
Number subjects showing autonomic response	13	18	11

(Mean values in three groups of 30 subjects)

A comparative summary of tests results is presented in *Table IV*.

It is readily apparent that no significant difference in average after-nystagmus time exists between the mild "vertigo" susceptible and severe "vertigo" susceptible groups. The test data in *Tables V, VI* and *VII* indicate a wide dispersion of after-nystagmus times in both groups and in the controls.

The average after-nystagmus times of all three groups is not significantly

sensitivity tests are of little value in predicting ability to learn to fly or ability to accomplish acrobatics

Although after-nystagmus time is not significantly different in the two study groups it is quite apparent that a significant difference does exist with respect to autonomic response. It was noted that the autonomic reactions were much more frequent and more severe in the "vertigo" susceptible group, *(severe)*, than in the *"vertigo" non-susceptible group, (mild)*. The autonomic reactivity of the controls was similar to that of the "vertigo" susceptible group. These differences in autonomic response may possibly be of significance These results may indicate that the "vertigo" non-susceptibles tend to have a smaller total response to labyrinthine stimulation and are therefore more capable of resisting the disorientation influences of unusual motion. The importance of total reactivity and autonomic sensitivity will assume greater proportions under flight conditions where human stress factors are multiple and varied No definite conclusions can be drawn from this study, however a trend is indicated and additional studies should be accomplished to determine its constancy and significance.

Review of "vertigo" accidents

A review of major aircraft accident trends in USAFE since 1952 reveals

total absence of any discussion concerning "vertigo" at the December 1953 USAFE Fighter Symposium The report of this symposium pinpoints all significant cause factors in aircraft accidents and "vertigo" is conspicuous by its absence in the light of events since that time During the past two years numerous fatal accidents have occurred in which "vertigo" was implicated as the primary cause factor The increased incidence of this type accident was so striking that a programme of reindoctrination of all pilots in the psychophysiological aspects of spatial disorientation was initiated in the USAFE Command. The cause of this unusual increase in incidence of "vertigo" accidents is not understood, however a number of contributing factors are discernible Some of the more important of these are (1) NATO build-up with new units, (2) large in-put of relatively inexperienced pilots, (3) accelerated training to create all-weather combat capability, (4) conversion of units to new aircraft

Security requirements will not permit publication of accident rate data

Table V. Controls

Subject	Barany Stimulation Nystagmus Duration Following Rotation (sec)				Autonomic response to coriolis stimulation. Standard Rotation once per 2 sec for Maximum of 30 sec and 4 Oscillations of Head						
	Horizontal Canals		Vertical Canals		No Osc	Blood Pressure		Systolic Change	Nausea	Pallor	Sweating
	R	L	R	L			After				
1	19	18	11	11	4		124/76	−10	0	0	0
2	20	18	12	12	4		130/80	0	0	0	0
3	22	21	13	13	4		132/70	+ 8	0	0	0
4	16	13	11	11	4		118/68	+ 6	0	0	0
5	24	22	11	—	0		144/84	− 6	+	+	+
6	14	13	—	—	0		120/78	−10	+	+	+
7	22	22	—	—	0		138/92	−16	+	+	0
8	21	22	11	11	4		140/96	+ 2	+	+	+
9	27	26	13	13	4		138/94	− 6	0	0	0
10	25	22	12	12	4		138/76	+ 2	0	0	0
11	21	19	13	12	4		114/74	−14	0	0	+
12	18	18	11	12	4		120/84	−12	0	0	0
13	17	15	10	9	4		150/90	+ 4	0	0	0
14	16	14	11	11	4		124/88	−14	0	0	0
15	19	17	13	13	1		108/68	−10	+	+	+
16	13	12	9	10	4		142/84	+ 6	0	0	0
17	18	14	11	12	4		114/80	− 8	0	0	0
18	20	18	14	14	4		128/78	− 8	0	0	0
19	17	17	13	13	4		150/92	0	0	+	+
20	14	15	10	10	0		156/110	− 8	+	+	+
21	13	13	9	9	4		168/118	+ 4	0	0	+
22	19	17	12	12	4		138/76	+ 2	0	0	0
23	17	17	11	10	4		126/84	−10	0	0	0
24	20	20	14	16	4		118/80	− 4	+	+	+
25	18	20	15	13	4		130/76	+ 4	0	0	0
26	28	30	14	15	4		140/88	+16	+	+	0
27	18	19	14	14	4		108/70	−14	+	+	0
28	19	18	13	13	4		138/80	− 6	0	0	0
29	15	14	11	12	4		122/70	− 8	0	0	0
30	16	14	10	10	4		186/90	− 8	+	+	+

Table VI. Susceptible Subjects

Subject	Experience Flying time (in hr)		Barany Stimulation Nystagmus Duration Following Rotation (in sec)				Autonomic Response to Coriolis Stimulation Standard Rotation 1x per 2 sec for Maximum of 50 sec and 4 Oscillations of Head						
			Horizontal Canals		Vertical Canals		No Osc	Blood Pressure		Systolic Change	Nausea	Pallor	Sweating
	Total	Jet	R	L	R	L		Before	After				
1	3150	850	18	23	11	12	4	130/70	118/72	−12	+	+	+
2	4200	800	13	11	12	12	4	136/102	126/84	−10	+	0	0
3	1775	81	30	25	15	15	0	160/100	144/94	−16	+	+	0
4	950	650	15	14	13	12	4	158/98	130/88	−28	0	0	0
5	1100	850	16	12	11	11	4	154/105	152/100	− 2	0	0	0
6	2300	300	19	23	11	12	4	136/86	124/90	−12	+	0	0
7	2200	700	21	21	16	14	0	126/76	120/80	− 6	+	+	0
8	630	420	25	20	12	12	4	120/74	128/80	+ 8	+	0	+
9	630	420	16	13	15	15	4	124/76	130/80	+ 6	0	0	0
10	640	450	16	15	15	13	4	120/78	102/70	−18	+	0	0
11	530	300	17	17	14	14	4	150/82	128/80	−22	+	0	0
12	800	550	19	20	10	10	0	148/84	142/84	− 6	+	0	0
13	1880	610	21	18	12	9	4	150/92	154/90	+ 4	0	0	0
14	1200	850	23	26	12	12	0	120/80	120/84	0	+	0	0
15	2200	300	24	23	12	12	4	144/80	118/78	−26	0	0	0
16	2300	700	14	9	8	7	4	128/76	122/76	− 6	0	0	0
17	1200	650	20	19	15	16	4	118/72	110/80	− 8	+	0	0
18	1025	750	14	17	11	11	4	128/74	112/78	−16	+	0	0
19	540	350	20	20	13	10	0	132/90	124/86	− 8	0	0	0
20	500	300	18	18	10	12	4	126/70	120/74	− 6	+	0	+
21	2450	1200	22	21	11	12	0	140/80	122/82	− 8	+	+	0
22	500	300	21	20	13	12	4	134/78	124/78	−10	0	0	0
23	1250	820	20	18	14	11	4	140/80	132/80	− 8	0	0	0
24	500	250	14	12	11	10	0	132/88	130/80	− 2	+	0	+
25	2600	1780	18	19	13	11	4	150/88	144/92	− 6	0	+	+
26	875	600	24	22	15	15	4	128/70	122/70	− 6	+	+	0
27	550	250	18	18	11	11	4	130/90	130/84	0	0	0	0
28	450	250	16	15	9	10	4	132/86	128/86	− 4	0	0	0
29	815	600	20	22	11	11	3	110/82	110/84	0	+	+	0
30	850	500	17	15	12	12	4	124/78	120/70	− 4	0	0	0

Table VII. Non-susceptible Subjects

Subject	Experience Flying Time in hr		Barany Stimulation Nystagmus Duration Following Rotation (in sec)				Autonomic Response to Coriolis Stimulation Standard Rotation 1x per 2 sec for Maximum of 50 sec and 4 Oscillations of Head						
			Horizontal Canals		Vertical Canals		No Osc	Blood Pressure		Systolic Change	Nausea	Pallor	Sweating
	Total	Jet	R	L	R	L		Before	After				
1	950	650	17	16	13	14	4	144/88	136/90	− 8	+	0	0
2	575	380	14	14	13	14	4	146/90	140/90	− 6	0	0	0
3	550	300	22	25	14	14	4	140/80	138/74	− 2	0	0	0
4	2600	700	17	15	12	11	4	140/72	130/70	−10	+	0	0
5	965	700	19	19	12	12	4	122/82	134/82	+12	0	0	0
6	1600	800	15	14	14	16	4	120/86	126/80	+ 6	0	0	0
7	3000	500	25	23	15	13	4	130/76	118/74	−12	0	+	0
8	2700	700	19	21	12	11	4	126/78	120/70	− 6	0	0	0
9	550	350	18	18	13	14	4	136/72	136/82	0	+	0	0
10	700	500	17	22	14	12	4	120/84	120/84	0	+	0	0
11	3750	450	14	16	11	10	4	120/80	120/80	0	0	0	0
12	2460	800	15	18	14	13	4	142/78	138/76	− 4	+	0	0
13	900	650	19	17	13	14	4	136/82	146/86	+10	0	0	0
14	650	400	17	17	13	12	4	130/80	134/86	+ 4	0	0	0
15	500	380	17	14	14	13	4	126/94	145/90	+19	0	0	0
16	3000	800	21	18	12	12	4	138/90	130/84	− 8	0	0	0
17	640	400	15	16	12	12	4	140/80	134/76	− 6	0	0	0
18	2000	750	22	26	14	15	4	130/80	130/86	0	0	0	0
19	3000	500	13	14	18	20	4	136/86	130/80	− 6	+	0	0
20	2800	50	22	26	15	15	4	136/94	134/94	− 2	0	0	0
21	1300	110	13	11	9	9	4	135/90	120/86	−15	0	0	0
22	600	410	17	17	14	13	4	135/90	140/90	+ 5	0	0	0
23	1175	870	20	22	16	17	4	138/80	130/70	− 8	+	0	0
24	2800	1400	19	21	11	11	4	130/84	120/90	−10	+	0	0
25	3900	500	14	13	12	13	4	138/80	138/90	0	0	0	0
26	1455	950	22	19	17	16	4	130/74	124/78	− 6	0	0	0
27	1001	750	20	21	12	11	4	126/90	126/92	0	0	0	0
28	2500	1200	17	15	11	11	4	138/104	142/94	+ 2	0	0	0
29	2600	100	26	24	11	11	4	132/82	126/82	−10	0	0	+
30	725	400	14	13	11	11	4	140/72	136/70	− 4	0	0	+

by the fact that "vertigo" accounted for approximately 14 per cent of the fatal accidents in USAFE during the past two years.

It is quite obvious that a problem exists, however it does not necessarily follow that "pilot's vertigo" *per se* is the culprit of exclusive importance in these accidents There are so many variables in any accident, both known and unknown, that it is impossible in many cases to sort them out and determine which are most important This is particularly true of fatal accidents.

Study of these "vertigo" accidents fails to reveal any common pattern in the events leading up to the accident situation. It is also apparent that many questions are left unanswered What was the pilot's general condition? Was hypoxia involved? Carbon monoxide? Did he panic from lack of confidence? Was there instrument malfunction? It is true that some of these questions can be answered, but not all of them

The criteria for establishing an accident as a "vertigo" type for Air Force statistical studies are two. The pilot involved must indicate by radio transmission that he has "vertigo" or a competent observer must have seen the aircraft enter an unusual attitude or manoeuvre with no apparent cause

accidents in which "vertigo" is a cause factor. For this reason there are probably many accidents involving vertigo which are classified as "cause undetermined" A significant percentage of fatal accidents are in this category.

Although no definite pattern is discernible in the above accident cases there are some important factors which are common to one or more in this group. One outstanding factor is that of inexperience of the pilot. Specifically, inexperience or lack of recent experience as related to the aircraft and flight conditions under which the accident developed and occurred

Another common factor is that of head movements during a procedure turn. In the questionnaire survey series, this was noted to be a factor considered by pilots as productive of disorientation. The mechanism of producing disorientation in this circumstance may be the Coriolis effect or more probably miscontrol from the head and hand movements involved with a resultant unusual attitude and "vertigo" which starts a series of events resulting in an attitude difficult to correct. This is critical if it occurs at low altitude A change in radio channels made just prior to the beginning of difficulties as a factor has been noted in a number of fatal accidents and could be significant. In many models of the F86 aircraft it is necessary to shift stick control from the right to the left hand then turn the head and look down and back in order to select the proper radio channel with the right hand If this is attempted in critical situations it may readily result in miscontrol. This deficiency in cockpit design is being corrected in new aircraft.

The factor of time requirement in sudden transitioning from one frame of reference to another is also important. Trials in tactical units have indicated that an average of 45 sec is required for a pilot to shift from one frame of reference, (e g another aircraft in formation) during a manoeuvre, to another frame of reference (instruments) and regain full control of the aircraft. This time requirement becomes critical under conditions of mental stress, low visibility and low altitude.

The factor of "semi-contact" flying may also be of importance. It was noted in the survey examples of disorientation under night flying conditions that a tendency to fly both instruments and contact existed and frequently resulted in confusion.

The factor of mental stress under instrument flight conditions is always an unknown quantity. There is no doubt that apprehension, uncertainty, and fear frequently occur, resulting in tenseness, over-control, miscontrol, judgement errors and even panic or mental blocking. These things occur in a variable degree in many individuals. Inadequate experience with resulting lack of confidence is apt to promote such reactions under instrument flying conditions, when smooth precision control of the aircraft by rapid instrument reference is mandatory. The margin of allowable error in high-performance aircraft is unfortunately, small.

The factor of instrument failure also frequently remains an unknown quantity. It is known that many flight instrument failures occur, although cases in which all instruments fail are rare. However, it is quite possible that many pilots depend too much on one instrument without adequate cross-checking. In such cases malfunction of one instrument can result in a critical situation. It is quite remarkable that in the questionnaire survey *there were only two cases of disorientation in which flight instrument failure* was indicated. The significance of this low number is unknown however, inasmuch as no specific comment regarding instrument failure was requested.

In view of the many possible "factors" involved in disorientation type accidents it is very difficult to determine the relative importance of "vertigo" itself as a causal factor in aircraft accidents. It is believed valuable information in this regard would be realized from careful and detailed studies of disorientation "near accidents" with an effort to obtain from the pilot, minute and specific details of events leading to the near accident situation. Certainly, the information available from studies of fatal accidents of this type is inadequate.

Discussion

This study indicates that spatial disorientation of varying degrees is universally experienced by pilots. Further, it has been determined that pilot "vertigo" continues *to be a problem among experienced pilots* under operational flying conditions. However, the magnitude of the problem from the standpoint of flight safety is difficult to determine and precipitate judgement based on inadequate study should not be permitted either to over- or under-emphasize p[illegible] area.

The results of the [illegible] minimize the importance of spatial [illegible] safety problem. This conclusion is partially drawn from the fact that most pilots recognize the occurrence of "vertigo" but also feel that adequate training and experience will assure the capability of maintaining aerial equilibrium and orientation under all flight conditions. The second point in favour of this conclusion is the apparently *low incidence of "vertigo" near-accidents.* Six hundred and eighty-five pilots indicated having had perhaps many thousands of "vertigo" experiences, but only 20 incidents were recorded

which were considered to be "near-accidents". In only 5 of the incidents were the pilots unable to recover on instruments. These 5 recovered on contact after breaking out of the weather. Therefore, it may be reasoned that, while the number of "vertigo" experiences is exceedingly large, the loss of aircraft control as a result of them is relatively infrequent.

On the other hand, the results of the aircraft accident review tend to emphasize the importance of spatial disorientation as a flight safety problem if one looks only at the percentage of major accidents attributed to pilots' "vertigo". Certainly, 4 per cent of major and 14 per cent of fatal accidents

these accidents would not have occurred, if the pilots' level of training and experience had been commensurate with the operational flight conditions to which they were exposed The existence of "vertigo" would, under such circumstances, be inconsequential Consideration of other factors frequently involved in these accidents also tends to dilute the importance of "vertigo" *per se*. For example, the hazard value of the time required to transition from one frame of reference (wing formation) to another (instruments) can be partially attributed to the lack of more ideal instrumentation, which will permit more rapid and accurate interpretation of aircraft attitude and indicated corrective action Time is vital to the pilot of a high-performance aircraft leaving no margin for errors or delayed decisions The engineers and designers persist in exceeding the saturation point of the pilot's mental faculties. This problem is further compounded on many occasions by the natural stresses of flight, including apprehension, anxiety and fear Errors in cockpit layout requiring unnecessary head movements and hand shifts on sensitive controls have also been implicated in "vertigo" accidents.

It is quite obvious that the possibility exists that "vertigo" may become a convenient whipping boy for other faulty conditions and hence may delay their recognition and correction. This does not mean that the fact of

Some action areas which may be considered to be linked with the "vertigo"

that in most instances the "vertigo" susceptibles have been able to cope with the circumstances of disorientation in spite of their autonomic hyper-reactivity to labyrinthine stimulation. From a practical standpoint, one is tempted to question the results of clinical labyrinthine testing as being applicable to flight disorientation problems. This doubt is suggested by the fact that the stimulus used in the Barany clinical test is 1000 times threshold, whereas the in-flight stimuli affecting the labyrinthine system and productive of "vertigo" are often a combination of sub-threshold and threshold or at most a few times threshold.

The importance of indoctrination of all pilots in the physiological principles and mechanisms of development of spatial disorientation is well recognized. This study indicates that perhaps the original indoctrination would have been more effective, if practical demonstrations of labyrinthine sensation unreliability had been more frequently utilized. It is also apparent from the study that refresher indoctrination at periodic intervals is of definite value. The lack of an appropriate training film for this purpose is considered to be an unfortunate void.

The possibility is suggested by this study that our present training and proficiency requirements with respect to precision instrument flying in high-performance aircraft under present operational conditions are not adequate There may be some question as to whether or not these requirements have kept pace with aircraft performance and new operational procedures Improvements in this problem area will be highly productive in eliminating some of the mental stress factors which are known to be of utmost importance in pilot performance under adverse circumstances.

It is recognized that a great deal of effort is being made to improve instrument design and display, to improve and standardize cockpit layout, to develop more useful and accurate flight instruments and to minimize the environmental stresses to which the pilot is subjected. One is forced to wonder, however, whether enough consideration is given to the saturation point of human mental faculties in the relationship to the flying task requirements under all operational conditions It is suggested that perhaps more studies should be accomplished in operational units to determine the adequacy of existing equipment, techniques and procedures to safely permit the pilot [illegible] accomplish all operational requirements. It is apparent

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more adequate proficiency evaluation techniques and procedures

The foregoing emphasis upon the indirect method of approach toward the solution of the problems of pilots "vertigo" is believed to be the most practical approach and one which will bring more immediate results. The

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SUMMARY

A study of spatial disorientation in operational flying has been accomplished. Six hundred and eighty-five pilots from the USAFE Command have been

surveyed by the questionnaire method to obtain information regarding the incidence and significance of pilot's "vertigo" in operational units. A series of labyrinthine sensitivity tests were conducted on "vertigo" susceptible pilots, "vertigo" non-susceptible pilots and non-pilot controls. A review of USAFE Command major aircraft accidents for a period of two years was made to determine the relative importance of pilot's "vertigo" as a primary cause factor in aircraft accidents.

The results of the questionnaire and interview survey produced the following major items of information:

(I) Spatial disorientation of varying degrees is experienced by all pilots.

(II) Spatial disorientation continues to be a significant flight safety problem in operational units.

(III) Only 32 severe disorientation incidents were recorded although it was indicated that "vertigo" experiences number in thousands. Twenty of the 32 recorded severe experiences were considered to be in the "near accident" category.

(IV) Typical examples of severe and moderate "vertigo" experiences were recorded in the report.

(V) Severe "vertigo" experiences were 5 times as frequent among jet pilots as among non-jet pilots.

(VI) Almost 100 per cent of recorded disorientation incidents were of the "attitude and motion" type. Visual illusions, autokinesis and hypnogenic states were rarely recorded.

(VII) The flight condition most frequently recorded as a cause of "vertigo" was day-weather formation (wing reference).

(VIII) Some contributory factors of special interest were head movements and shift of hand controls during a manoeuvre under IFR conditions, fatigue, "hangover" and "lay-off" periods.

(IX) An overwhelming majority of pilots either do not consider "vertigo" to be an important problem or consider it to be a circumstance of flight which can be adequately dealt with through proper training and practice.

(X) Discussions with pilots indicated that initial indoctrination in the psychophysiology and mechanism of disorientation in flight could be made more effective by demonstrations of labyrinthine unreliability in the Barany Chair or Link trainer.

: labyrinthine sensitivity studies accomplished on "vertigo" suscepti-"vertigo non-susceptibles", and controls resulted in the following ions.

io significant correlation exists between labyrinthine sensitivity as etermined by after-nystagmus time and susceptibility to spatial orientation as determined in the questionnaire and interview survey. e total effects of marked labyrinthine stimulation, as indicated by onomic responses, are significantly greater in "vertigo susceptibles" , in "vertigo non-susceptibles".

of "vertigo" aircraft accidents occurring in the USAFE Com-g 1954–55 and 1955–56 revealed the following information: to 1 January 1954 "vertigo" was apparently not recognized to

be of significance as a cause of aircraft accidents in operational flying in the USAFE Command.

(II) During the past two years a marked change in this respect has occurred and Pilot's "vertigo" has been implicated as a primary cause factor in 4 per cent of major accidents and 14 per cent of fatal accidents.

(III) Some probable factors involved in this change are: NATO build-up, accelerated training to attain all-weather combat capability, large in-put of new pilots of low experience level, and conversion of units to new aircraft.

(IV) Ten typical examples of "vertigo" accidents were presented in the report.

(V) Review of "vertigo" accidents revealed no common sequential pattern leading up to the occurrence of an accident. However, several factors appeared which were common to one or more of these accidents. Those factors considered most important were:

(a) Inadequate total or recent experience in the flight conditions under which the accident occurred (6 in the 10 accidents presented).

(b) Head movements and shift of stick control from right hand to left to effect radio channel change during flight manoeuvre under IFR conditions (2 in the 10 accidents presented).

(c) The transition time requirement in sudden change from one frame of reference to another, particularly from wing reference to instrument reference (4 in the 10 accidents presented).

(d) "Semi-contact" flying with division of attention between two frames of reference (3 in the 10 cases presented).

(e) Mental stress.

(VI) The possibility of the existence of other factors such as instrument failure, poor physical and mental status of the pilot, hypoxia, toxic agents, hypoglycemia or fatigue requires consideration in accidents of this type.

The implications of pilot's "vertigo" as a significant flight safety problem area were discussed. Certain recommendations regarding the problem of spatial disorientation were suggested by the discussion. Some recommendations which may merit consideration are as follows:

(I) Initial indoctrination of student pilots in the psychophysiology of spatial disorientation should include a demonstration of the unreliability of labyrinthine sensory cues as a means of orientation. The Barany Chair can be used for this purpose.

(II) A training film should be prepared for initial and refresher indoctrination on the subject of spatial disorientation in flight.

(III) Detailed studies should be made of disorientation "near accidents" with an effort to obtain from the pilot, minute and specific details of events leading to the "near accident" situation.

(IV) Operational studies should be accomplished to determine the time requirement for transitioning from wing reference (formation flying) to instrument reference during a manoeuvre. Techniques for shortening this time requirement should be developed if possible.

(V) [illegible]

(VI) Studies of adequacy of present training, proficiency, and check-out requirements for all operational aircraft under all operational conditions should be made to determine whether such requirements are keeping pace with aircraft performance and new operational tactics. These requirements should be correlated with the experience level of the present average pilot entering operational squadron service

This study indicates that spatial disorientation and related factors constitute a significant flight safety problem area in operational units It is a complex problem area involving many diverse factors such as physiological status of the pilot, flying techniques, flight tactics, training and proficiency requirements, cockpit layout and flight instrument design which collectively overshadow in importance the central core of pilot's "vertigo", *per se.* Further studies should be accomplished to evaluate the relative role played by all involved factors which contribute to the establishment of spatial disorientation as a significant flight safety problem in operational flying.

Sommaire

Le vertige de l'aviateur est la cause de nombreux accidents aériens au cours de l'instruction, à l'école de pilotage, par suite d'inexpérience. Mais, même chez les pilotes confirmés, dans les Formations aériennes, la désorientation spatiale continue à être un facteur non négligeable d'accidents et d'incidents. C'est ce qui légitime la présente enquête, faite dans les escadres opérationnelles de l'USAF en Europe.

685 *pilotes brevetés (chasseurs, bombardiers, intercepteurs, bombardement léger, etc. .) soit "sensibles au vertige", soit "insensibles au vertige", ayant en moyenne* 1625 hr *de vol, dont* 450 *sur Jet, ont été soumis*

(I)—à un questionnaire *détaillé comprenant les incidents hypoxiques, l'hyperventilation, le mal de décompression, la désorientation en vol, la décompression explosive ou rapide, les problèmes d'équipement personnel. Les questions relatives à la désorientation spatiale comportaient fréquence, symptomes, conditions de vol, effet sur la conduite de l'avion, circonstances de la récupération, etc. . . .,*

(II)—à une série de tests de sensibilité labyrinthique standardisés sur le fauteuil de Barany, avec mesure de la durée du nystagmus post-rotatoire (Ces tests ont été subis par les pilotes de Jet seulement).

La circonstance la plus habituelle est le vol en formation par mauvais temps. Rares sont les cas d'illusions visuelles (confusion des lumières avec les étoiles, vertige auto-cinétique) Deux tableaux détaillés indiquent d'une part la fréquence de la désorientation en fonction des conditions du vol, d'autre part l'opinion des pilotes sur les moyens de récupérer après désorientation ou d'en éviter les effets (Ils recommandent la pratique et l'entraînement, ainsi qu'une information supplémentaire sur le mécanisme et la physiologie de la désorientation.)

A cet égard, les épreuves de sensibilité labyrinthique ont éveillé chez eux beaucoup d'intérêt La conclusion générale de ces tests est qu'il n'y a pas de

corrélation significative entre la sensibilité labyrinthique (durée du nystagmus post-rotatoire) et la sensibilité au vertige. Ce résultat concorde avec celui d'autres recherches ayant montré que les tests de sensibilité labyrinthique sont de peu de valeur pour la prédiction de l'aptitude à voler et à exécuter des acrobaties. Par contre, les réactions "autonomes" sont plus fréquentes et plus sévères chez les sujets sensibles que chez les non-sensibles au vertige. Cette question mérite d'être approfondie.

Les auteurs ont procédé ensuite à une revue complète des accidents majeurs survenus dans l'USAFE pendant les deux dernières années, ce qui leur a permis de mettre en valeur certains accidents attribuables au "vertige de l'aviateur" et dont le nombre va croissant, alors qu'il n'en était pas fait mention avant 1952. *Leur taux est actuellement d'environ* 4 *pour cent, avec une mortalité de* 14 *pour cent, du total des accidents mortels. Dix observations caractéristiques et détaillées, qu'il faut lire dans le texte, sont rapportées à titre d'exemple.*

Bien qu'il soit impossible de donner une réponse à toutes les questions que posent les accidents de cette nature, leur classification dans la catégorie "due au vertige" repose sur deux critères. le pilote indique par radio qu'il a le vertige, ou bien un témoin compétent a vu l'avion prendre une attitude inhabituelle ou exécuter une manoeuvre sans cause apparente, Beaucoup d'accidents dits "de cause indéterminée" entrent dans ce nombre. Dans ceux qui ont été relatés ci-dessus il faut souligner la fréquence de l'inexpérience du pilote, en particulier dans le vol de nuit ou tous-temps. Un deuxième facteur est le mouvement de tête pendant le vol en courbe (Coriolis). Enfin il faut tenir compte du temps nécessaire pour le passage d'un système de référence visuelle (vue extérieure) à un autre système (tableau de bord) dans certaines conditions de tension mentale, mauvaise visibilité, basse altitude, etc. . . . La désorientation peut naître du désir de voler à la fois aux instruments et au contact. Les facteurs "mental stress" et défaillance des instruments, sont difficiles à apprécier. L'étude des incidents serait, à cet égard, plus instructive que celle des accidents mortels.

En résumé, le problème de la désorientation spatiale existe chez les pilotes [illegible]

le temps nécessaire au passage au vol aux instruments, éviter les mouvements de tête, etc. . . . Mieux qu'une sélection basée sur les tests d'hyperexcitabilité labyrinthique, une indoctrination minutieuse et surtout fréquemment répétée constituera une prévention efficace.

Il n'y a là qu'un aspect particulier d'un [illegible] *l, qui est celui des limitations humaines* [illegible] *de l'avion à* [illegible] *soumis à toutes les exigences* [illegible]

[illegible]NCES

ARMSTRONG, H. G. [illegible] of [illegible]
1952.

CLARK, BRANT and NICHOLSON, M. A. "Aviator's Vertigo: A Cause of Pilot Error in Naval Aviation Students". *J. Aviat. Med.* **25**, 171—179, 1954.

Report of USAFE Fighter Symposium, 15–18 December 1953.

VINACKE, W. E. "Aviator's Vertigo". *J. Aviat. Med.* **19**, 158–170, 1948.

VINACKE, W. E. "Illusions Experienced by Aircraft Pilots". *J. Aviat. Med.* **18**, 308–325 1947.

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En résumé, le problème de la désorientation spatiale existe chez les pilotes [illegible] *en vol, si* [illegible] *ible, et se* [illegible] *u vertige, mais la perte du contrôle de l'appareil est relativement rare. D'autre part, la revue* [illegible] *le temps nécessaire au passage au vol aux instruments, éviter les mouvements de tête, etc. . . . Mieux qu'une sélection basée sur les tests d'hyperexcitabilité labyrinthique, une indoctrination minutieuse et surtout fréquemment répétée constituera une prévention efficace.*

Il n'y a là qu'un aspect particulier d'un problème plus général, qui est celui des limitations humaines dans l'emploi de l'avion à hautes performances soumis à toutes les exigences opérationnelles.

REFERENCES

ARMSTRONG, H. G. *Principles and Practice of Aviation Medicine.* Third edition, 1952.

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En résumé, le problème de la désorientation spatiale existe chez les pilotes

des accidents majeurs et mortels montre que, pour la plupart, ils ne se seraient pas

rinthique, une indoctrination minutieuse et surtout fréquemment répétée constituera une prévention efficace.

Il n'y a là qu'un aspect particulier d'un problème plus général, qui est celui des limitations humaines dans l'emploi de l'avion à hautes performances soumis à toutes les exigences opérationnelles.

References

ARMSTRONG, H. G. *Principles and Practice of Aviation Medicine.* Third edition, 1952.

eye, the vestibular apparatus and the proprioceptive sensory mechanisms together with a comprehensive system of postural and righting reflexes suitable for the execution of appropriate patterns of muscular response.

Unfortunately these mechanisms are not so well adapted to the new environment of a pilot in the air. In the first place both vestibular and proprioceptive sensory information can no longer be relied upon, owing on the one hand to continuous variations in both magnitude and direction of the apparent gravitational field and on the other to the protracted nature of the rotational movements to which a pilot is normally exposed. Consequently all responsibility for acquiring reliable information is thrown upon the eyes. In the second place central nervous integration of available information is doubly complicated, on the one hand by the necessity for sifting reliable from unreliable information, and on the other hand by the fact that an aircraft in flight is exposed to the 6 degrees of freedom permitted by three-dimensional space (3 in translational motion and 3 in rotational motion). Finally, in the third place, the effective muscular response must be directed through new channels appropriate to maintenance of aircraft control, rather than maintenance of balance and posture by means of weight bearing muscles, and as a consequence a pilot is forced to contend with control characteristics which are not always well matched to his natural aptitudes.

It is not to be wondered at, therefore, that whereas on the ground disorientation is seldom experienced without there being some underlying pathology, disorientation in the air is not an infrequent occurrence in the absence of any pathological cause, particularly so since the one reliable channel of sensory information which is left to a pilot in the air, namely that of vision, is frequently restricted to the indirect visual cues afforded by the aircraft's flight instruments. Indeed it has been said by a reliable authority that "disorientation under instrument flight conditions is probably the most common cause of fatal accidents not due primarily to mechanical failure" (RUFFELL SMITH, 1956). In such instances, however, when the only reliable witnesses lie dead among the wreckage it is not easy to attribute the loss of control to its proper cause and hence the unpleasant truth of the matter is that the greater number of these disasters must necessarily fall into the category of the *Unexplained Accident*.

The writer was particularly fortunate therefore, when given occasion to investigate an instance of loss of control attributed to disorientation, in which control was subsequently regained, and in which the aircraft concerned was fully equipped with automatically recording instruments and was piloted by an experienced test pilot of high intellectual calibre.

LOSS OF CONTROL DURING A SINGLE RAPID ROLLING MANOEUVRE

The incident referred to occurred at about 10,000 ft and 300 knots indicated air speed and was the result of a rapid rolling manoeuvre carried out in an aircraft capable of unusually high rates of roll. A few seconds after commencement of the roll the pilot attempted a normal recovery but after the initial attempt to do so the situation grew completely out of hand and he abandoned further efforts taking hands and feet off the controls. Fortunately the aircraft sorted itself out and when control had ultimately been regained could

DISORIENTATION DUE TO RAPID ROTATION IN FLIGHT

(A Cause of Unexplained Aircraft Accident?)

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Difficulties which may be associated with manoeuvres involving rapid rotation in flight are described. These difficulties are discussed first in connexion with loss of control in a single very rapid rolling manoeuvre and second in connexion with certain findings from a field enquiry into the causes of pilot disorientation.

[illegible]

to derangement of normal neuromuscular mechanisms as a result of vestibular stimulation.

It is concluded that vestibular stimulation during and immediately after manoeuvres involving rapid rotation can jeopardize the reliability of visual sensory information, and that the possibility of similar interference with other neuromuscular mechanisms cannot be ignored.

Finally, it is emphasized that the significance of such interference in man-controlled flight is as yet ill defined, and it is suggested that here is a field of investigation which at the time of writing requires to be further explored.

Introduction

The following paper describes certain difficulties which may beset a pilot when executing a flight manoeuvre involving rapid rates of rotation. It is based in the main upon a single incident in which control was lost during recovery from a very rapid roll, and upon the outcome of a recent field inquiry into the causes of pilot disorientation. Before continuing however, it will perhaps be helpful to consider briefly the main factors concerned with the maintenance of orientation in man-controlled flight.

The successful maintenance of orientation by man in any dynamic environment essentially depends upon the fulfilment of three fundamental requirements. In the first place there must be adequate availability of reliable sensory information. In the second place this information must be properly integrated in the central nervous system and formulated into appropriate patterns of response In the third place, there must be effective execution of such response through the medium of the body musculature. Fortunately so long as man remains in his normal environment on the ground, these requirements are adequately met by the neuro-muscular mechanisms with which he is naturally endowed For he is provided with three largely independent and relatively reliable sources of sensory information, namely the

a correspondingly violent angular acceleration to the right (roughly 400°/sec²). After about 3 sec, when a rate of roll of roughly 330°/sec had been achieved, a corrective control movement was made. Immediately after this the rate of roll rapidly decreased but instead of coming to a halt as intended, a rapid roll in the opposite sense was initiated with a correspondingly high angular acceleration. Simultaneously a series of violent and somewhat uncoordinated movements occurred in all three primary controls and thereafter a series of violent rotational oscillations took place. From the available evidence it appears that it was after about 6 sec that the pilot abandoned conscious attempts at restoring control and it will be seen that subsequently the oscillations were relatively rapidly damped out. After about 12 sec it was possible to revert to manual control

The unusual character of the events portrayed in *Fig. 1(a)* can be judged by comparison with *Fig 1(b)* which shows the time course of the same variables during a similar, but slightly slower manoeuvre conducted by the same pilot in the same aeroplane, but in which control was retained throughout. It will be seen that in this manoeuvre the roll was relatively easily brought to a halt and control movements were smooth and altogether appropriate. The contrast between the two manoeuvres is striking and indicates clearly that whereas the slower one was well in hand throughout, yet in the faster manoeuvre it proved quite beyond the capacity of the pilot to master the situation which developed. In searching for an explanation there are two main questions which present themselves.

Firstly, were the intrinsic difficulties of regaining control from the situation which arose, too great for even a normal fully functional human expert to handle?

Secondly, was the manoeuvre likely to have caused disorientation of the man to the extent of interfering with his normal recovery procedure?

The intrinsic difficulties of regaining control

With regard to the former of these two questions, examination of *Fig 2* which is a composite presentation of the available data, shows that the intrinsic difficulties of the task presented to the pilot may well have been outside his normal capabilities. For it will be seen that the frequency of the oscillations in roll approached the very high figure of 1 c/s and it is well known that a sinusoidal oscillation having this order of frequency proves exceedingly difficult for a human operator to control

The main source of this difficulty is to be found in the relatively long human reaction time, assumed in this instance to be roughly 0 25 sec, and the additional delay in response introduced by the mechanics of the aircraft control circuit, also roughly 0·25 sec. Thus it will be appreciated that owing to the combined effect of these two sources of delay, at least half a second must elapse between the moment at which a decision is made and the moment at which the intended response can begin to take effect. The consequence of this may be traced in *Fig. 2*, where the points marked I, II, III and IV indicate the latest moments at which decision to effect the subsequent reversal of control (from right to left, or vice versa) could have been made by the pilot. In the first instance (I) the matter was well in hand. In the second instance (II) the decision, although taken while still rotating at 150°/sec to

be flown back to base in a normal manner. The pilot experienced seve[illegible] disorientation and has little memory of the confused period which followe[illegible] loss of control.

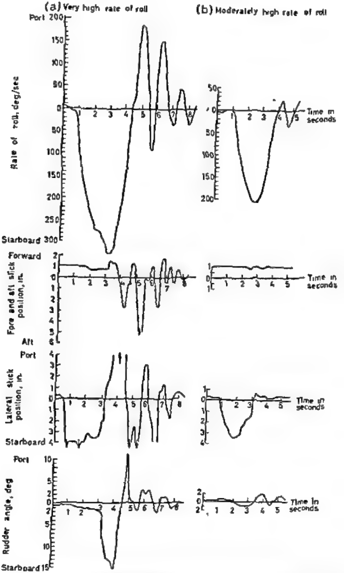

Fig 1 Comparison of the control movements during the very high rate of roll manoeuvre in which aircraft control was lost, with those for a moderately high rate of roll manoeuvre in which control was not lost

The episode can be traced by reference to *Fig. 1(a)*. In this figure the rate of roll of the aircraft and displacements of the three primary controls are separately plotted against time. It will be seen that an initial rather violent lateral stick movement was made to the right and the roll commenced with

reaching this state of affairs had he not been subjected to the severe strain imposed on the human body by high angular and linear accelerations, it is not possible to say. But it is possible to conclude that, having arrived at this dynamic situation it is unlikely that the pilot would have been able to restore control by his own efforts even if in full command of his faculties. That is to say, the theoretical limits determined by matching the intrinsic properties of man and machine, were in fact probably approached. It may well be however that such limits were in reality anticipated by a different although related factor, namely disorientation of the man, and the following is an attempt to assess the degree of disorientation which may have occurred.

The part played by pilot disorientation

The importance of this factor is evidenced by the fact that the pilot considers he experienced serious disorientation and that this was the main cause of loss of control. It remains, however, to try to determine what were the primary factors responsible for the disorientation incurred, and to this end the possible physiological consequences of exposure to the essential physical experiences as indicated by the recording instruments, are now examined.

In the first place, when rotation takes place about an axis through the body, the body fluids tend to separate along opposite radii and it has been shown that at high rates of rotation cardiac function may be greatly impaired (WEISS *et al.*, 1954). However, from the available data it is concluded that this effect of itself would probably not be sufficient to interfere materially with the body mechanisms at the rates of rotation and durations involved

Secondly, the records show that the pilot was subjected to negative acceleration of 1–2 G over a 2 sec period, followed by a sharp peak in the order of −3 G. However, although probably adding to his difficulties as a whole, this experience alone cannot be held as the major cause of disorientation.

Thirdly, owing to the oscillatory nature of the manoeuvre, rapidly changing lateral acceleration in the order of 1 G alternating from left to right about once every second must have been experienced and the pilot was aware of being violently shaken from side to side. Again this factor alone cannot be held solely responsible, but the pilot affirmed that it was not an inconsiderable one. It should be noted in addition that such accelerations acting upon the body may well have caused the pilot to throw his weight involuntarily upon the controls in an attempt to steady himself and thus may have been in part responsible for the wild control movements illustrated in *Fig. 1(a)*

Fourthly, the part played by the vestibular apparatus must be examined, for clearly the pilot was exposed to substantial accelerations both linear and angular throughout the manoeuvre. Unfortunately too little is known of the ways in which stimulation of the utricular and saccular maculae (end-organs sensitive to linear acceleration) can interfere with body mechanisms, for these organs to be further considered. But with regard to rotational experience it will be seen in *Fig.* 2 that this was exceptionally severe. The maximum rate of roll was 330°/sec to the right, achieved during roughly one revolution, and the angular acceleration was nearly all the time between 200 and 400°/sec², a steady state never being achieved. There is no doubt that at these orders of angular velocity and acceleration, the rotation-sensitive end-organs

the right, was too late and the control could not be reversed again in time to prevent initiation of a roll to the left. The decision to make the third control reversal (III) must have been taken almost at the peak velocity to the left and the final point (IV) decision would have had to be made to take off the left-hand control before this had even been applied.

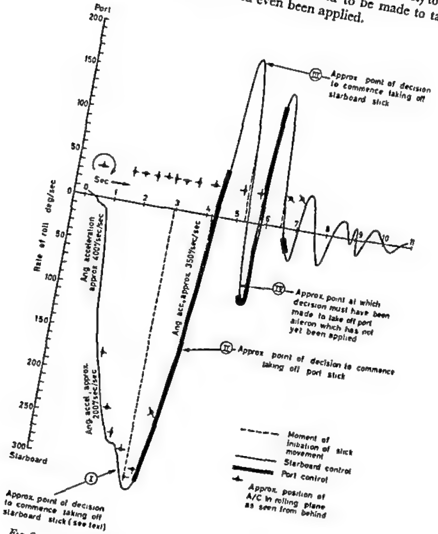

Fig 2 Selected data from records of the rolling manoeuvre referred to in the text

Such a situation is not necessarily an impossible one, since the power of learning might, at least in theory, allow it to be soluble by a human operator. But there is little doubt that even if this were the case, misjudgements would be common and in this single instance the pilot had no opportunity to practice the particular eventuality. Whether or no he would have avoided

In this incident, therefore, misleading sensation may have been experienced similar to that usually implied by the term "after-sensation of rotation", despite the fact that the durations involved were too short for the development of after sensations as usually understood by the terms.

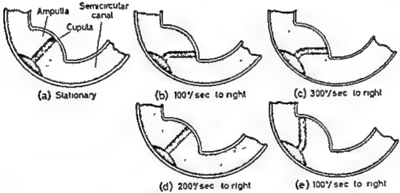

Fig 3 Diagrammatic illustration of the way in which sensation of rotation may at times have been opposite to that which was in fact occurring

Vestibular Interference with Vision During Prolonged Rotational Experience

In this single incident and in the absence of direct experimental evidence, interference with vision due to vestibular stimulation can of course be no more than conjecture. But the plausibility of this being the case during more prolonged rotational experience is somewhat greater since the experiences to be recounted below have been repeatedly reported by many different pilots. When spinning an aircraft, for example, if recovery is delayed for more than roughly 15–20 sec (about 5 turns when the spin is rapid) one's visual impression of the outside world quite suddenly becomes blurred and "streaky" and the rate of rotation appears to speed up when this is not in reality so When recovery action is then taken and the rotation is fairly

cockpit and horizon appear to rotate together at the same speed "Recovery was only effective" he said, "so long as I could keep a landmark on the horizon and a point on the cockpit coaming going round together at the same speed".

The two effects, namely difficulty of maintaining a clear visual impression of the outside world when the spin is prolonged, and the after-sensation of rotation experienced immediately after recovery, are almost certainly both attributable to the well known errors which develop in the rotation sensitive end-organs during, and immediately after cessation of, prolonged rotation. In the first place as the vestibular sensation dies away during the prolonged

(semi-circular canals) will have been violently stimulated. Indeed, in all probability the moving parts of the end-organs concerned will have been maximally displayed well before the maximal stimulus was attained (VAN EGMOND *et al.*, 1949). But it is well known that during angular movements, stimulation of the semi-circular canal tends to induce reflex responses in the extrinsic muscles of the eyes which assist them to follow the outside world and so maintain a steady image on the retina. It is also well known that when such stimulation is unusually strong the eye movements so induced tend to become *involuntary*. Hence it must be presumed that involuntary movements are likely to have been generated on this occasion.

The possible consequences of this contingency appear to be twofold. In the first place the induction of involuntary eye movements suitable to following the outside world might well have prevented the pilot from fixing his gaze upon the instrument panel in his aircraft. But in the second place the *rate of rotation* might well have been too great for compensatory eye movements to allow fixation upon the outside world either; particularly so since, as already mentioned, the angular velocities achieved were probably in excess of the maximum which can be registered by the end-organ concerned. It was interesting to hear from the pilot, therefore, that in practice he could *neither* fixate upon his instruments nor upon the external visual field at the higher rates of rotation. Only a blurred impression of alternating dark and light was obtained.

There is one additional possible consequence which should be here mentioned. Any rotational movement is in the nature of a vector having both magnitude and direction. As already mentioned, there are grounds for believing that magnitude of the angular velocity experienced was at times greater than the maximum which can be recorded by the semi-circular canals. But for this very reason there are also grounds for believing the sensation of direction of rotation may have at times been opposite to that which was in fact occurring. The source of this kind of error may be followed in *Fig.* 3. Let us suppose for the sake of argument that the maximum angular velocity [illegible] canal is 100°/sec. Before commer[illegible] part of the end-organ) [illegible] to the right for example it would then be fully deflected, or as we may say, up against the stops (*Fig.* 3(*b*)). During further rotation to the right it would remain here, in the fully deflected position, and hence the same condition would obtain at 300°/sec as at 100°/sec (*Fig.* 3(*c*)). But the moment deceleration begins the cupula would commence its return, and hence on reducing to an actual angular velocity of 200°/sec it would have returned roughly to the zero position (*Fig.* 3(*d*)). That is to say, no sensation of rotation would be experienced even though actual rotation were still in evidence. During the remainder of the deceleration the cupula would then be deflected to the left so that on having reduced the rate of rotation still further to 100°/sec (still to the right) the cupula would be deflected to the left, in the position shown in *Fig.* 3(*e*). That is to say, sensation would be of rotation to the left when the actual rotation was still to the right. At this point therefore a sensation of rotation would be experienced in the opposite direction to that which was in fact occurring.

constatations faites au cours d'une enquête sur les terrains, au sujet des causes de désorientation chez les pilotes.

Les difficultés rapportées se classent en trois catégories principales:

(I)—celles qui se produisent quand les changements de vol sont trop rapides pour être suivis par un opérateur humain,

(II)—celles qui sont dues à la violence physique de la manoeuvre,

(III)—celles qui sont dues à la désorientation des mécanismes neuromusculaires normaux par suite de la stimulation vestibulaire.

On en conclut que la stimulation vestibulaire pendant et aussitôt après des manoeuvres comportant une rotation rapide peut compromettre la valeur de l'information sensorielle visuelle, et que la possibilité d'une interférence analogue avec d'autres mécanismes neuromusculaires ne peut être ignorée.

Enfin on souligne que la signification d'une telle interference dans le vol avec pilote humain est encore mal définie, on suggère qu'il y a là un champ d'études qui, au moment où cet article est écrit, demande à être plus complètement exploré.

References

van Egmond, A. A. J., Groen, J. J. and Jongkees, L. B. W. "The Mechanics of the Semicircular Canals". *J. Physiol.* **110**, 1, 1949.

Graybiel, A. and Hupp, D. I. "The Oculogyral Illusion". *J. Aviat. Med.* **17**, 3, 1946.

Ruffell Smith, H. P. "Discussion on the Role of the Nervous System in Adaptation to High Performance Flying" *Proc. Roy. Soc. Med.* **48**, 45, 1956.

Weiss, H. S., Edelberg, R. and Charland, P. R. "Animal and Human Reactions to Rapid Tumbling". *J. Aviat. Med.* **25**, 5, 1954

spin, so the compensatory nystagmus of vestibular origin which normally assists visual fixation during rotational movement, may also be expected to die away. It may be expected, therefore, that difficulty would be experienced in establishing a stationary image upon the retina. In the second place, immediately after recovery, the difficulty may be attributed to the presence of such eye movements (nystagmus due to after stimulation of the rotation sensitive end-organs) when in fact rotation has ceased to occur.

During the enquiry referred to above it transpired that similar difficulties are experienced when a rapid rolling manoeuvre is prolonged beyond about 15–20 sec.

It does not seem at all improbable therefore that vestibular stimulation due to rapid rotation in flight can, when sufficiently severe, jeopardize the reliability of a pilot's visual mechanism, a conclusion which is the more significant when it is recalled that normally the eyes alone can provide information sufficiently reliable for maintenance of orientation during flight.

Conclusions

It will be seen from the above discussion that there are a number of different kinds of difficulty liable to be experienced by a pilot when exposed to rapid rotation during flight. In the first place it is possible for the rates of change incurred to be too great for human neuro-muscular mechanisms to follow the sequence of events. In the second place a pilot may suffer effects due to the physical violence of a manoeuvre. In the third place, and perhaps of greatest significance it seems that vestibular stimulation is liable to jeopardize the one channel of reliable sensory information available to a pilot, namely the visual one, by causing involuntary response in the extrinsic muscles of the eye.

It is perhaps not too presumptive to conjecture that such response is not entirely confined to these muscles alone. It is possible for example that when vestibular stimulation is sufficiently strong responses akin to, if not identical with, those already known to the physiologists as postural and righting reflexes may become manifest.

A considerable body of knowledge is now available concerning both reflexes such as these and the nature of the rotation sensitive end-organs responsible for their initiation. But it must be admitted that little is yet known as to how they can interfere with the ability of the pilot to fly an aeroplane and it is suggested that investigation of these factors in the context of Aviation Medicine should continue to be vigorously pursued. Indeed, it is anticipated that unless such interference can be more clearly defined in the near future, there will be an increasing number of incidents which, although in reality attributable to disorientation arising from this cause, will in the event have to be placed in the category of the unexplained accident.

Sommaire

Description des difficultés qui peuvent résulter de manoeuvres comporant une rotation rapide en vol. Ces difficultés sont exposées, en premier lieu, d'après un cas de perte de contrôle au cours d'un simple tonneau très rapide et ensuite d'après les

constatations faites au cours d'une enquête sur les terrains, au sujet des causes de désorientation chez les pilotes.

Les difficultés rapportées se classent en trois catégories principales:

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Enfin on souligne que la signification d'une telle interférence dans le vol avec pilote humain est encore mal définie, on suggère qu'il y a la un champ d'études qui, au moment où cet article est écrit, demande à être plus complètement exploré.

References

VAN EGMOND, A. A. J., GROEN, J. J and JONGKEES, L B. W. "The Mechanics of the Semicircular Canals". *J. Physiol.* 110, 1, 1949.

GRAYBIEL, A. and HUPP, D I "The Oculogyral Illusion" *J. Aviat. Med* 17, 3, 1946.

RUFFELL SMITH, H. P. "Discussion on the Role of the Nervous System in Adaptation to High Performance Flying". *Proc. Roy Soc. Med* 48, 45, 1956.

WEISS, H. S, EDELBERG, R and CHARLAND, P. R "Animal and Human Reactions to Rapid Tumbling" *J Aviat Med* 25, 5, 1954

UNCONSCIOUS EPISODES IN PILOTS DURING FLIGHT (1956)

T. J. POWELL, T. M. CAREY, H. P. BRENT and W. J. R. TAYLOR

RCAF Institute of Aviation Medicine, Toronto, Canada

DURING 1955, the IAM investigated nine aircrew, who had experienced episodes of unconsciousness or diminished consciousness while flying[1]. When the circumstances surrounding these cases were examined, it appeared that a synergy of physiological factors had been responsible for the disturbance in consciousness. None of these factors alone had been sufficient to cause loss of consciousness, but acting together, in susceptible individuals, they had produced serious disturbance in consciousness. The pertinent factors included hyperventilation, anxiety, hypoglycemia and prolonged l[illegible] G. [illegible] of the men demonstrated an onset of slo[illegible] hyperventilation phase. I[illegible] trigger[illegible] ce[illegible] ess[illegible] was [illegible]ecreased supply of the [illegible] brain. Whether anxiety had a direct effect [illegible], however, it may have been of importance in giving rise to hyperventilation.

The early onset of slow EEG waves with H.V. was thought to be associated with a subclinical epileptic diathesis, which, activated by the diminution in brain metabolism due to the other factors, had precipitated the episode of unconsciousness.

During 1956, eight further cases were examined at the IAM. Subjects whose unconsciousness was unquestionably due to hypoxia are not included in this series. Only five of the eight satisfy the criteria suggested for the syndrome of "Physiological Unconsciousness" in medically fit aircr[ew]. The factors are presumed to be:

(I) Established unconsciousness or diminished consciousness.
(II) Hypoxia excluded as a factor.
(III) The involvement of two or more of the following:
  (a) G
  (b) Hyperventilation
  (c) Hypoglycemia.
(IV) Should be reproducible under experimental conditions.

The cases described below have been grouped to bring similar types of cases together. No seasonal incidence is shown. The inexperienced individuals are those who exhibit most of the above factors. Apart from one individual, whose flying was below standard, the "physiological unconsciousness" occurred in students.

Case 1

This 19 year old navigator is employed on twin place interceptor aircraft. At 16 00 hrs while ascending to 31,000 ft, he suddenly became unconscious. The pilot realizing that something was wrong immediately descended to 25,000 ft, when the navigator started to recover consciousness He was *perfectly* conscious at *23,000 ft* and *felt well* except for a *slight headache*. He had been unconscious for about a minute. The flight was continued They climbed again and spent 30 min at 31,000 ft. There was no cabin pressurization Immediately before the flight the navigator had a doughnut and soft drink.

[illegible]

fit for all aircrew duties His resting EEG was borderline in that there were rhythmic bisynchronous 6 and 10 c/s waves of high voltage after 1 5 min of overbreathing. This continued for 1 min after H.V. ceased.

The EEG was *repeated fasting (B S. 70 mg per cent)* and a *similar pattern* was observed but the slow waves were 2–3 c/s. 100 g of glucose was given and he was subjected to 3·4 G for 5 sec one hour later (B S.80 mg per cent). No change from the resting pattern was observed. He hyperventilated for 45 sec and was again exposed to 3 4 G for 5 sec 1–4 c/s waves suppressed the alpha rhythm at the peak G Two and one-half hours after the glucose administration the B S. was 90 mg per cent, again the 3 4 G for 5 sec was [illegible]

the convulsion.

Despite this startling experimental finding he was allowed to return to full navigator duties but he was warned of his sensitivity to hypoglycaemia and concomitant hyperventilation. If he had been a pilot it is likely that he would have been given a limited flying category. His progress will be watched carefully.

Case 2

This is a 20 year old navigator on twin place interceptor aircraft. He has 400 hr of flying. They took off at 18.54 hrs and climbed to 30,000 ft in a few minutes. (It was found later that the navigator's last legible entry in the log was 18.58) Shortly after they reached altitude the navigator told the pilot he felt faint The pilot noticed there was no cabin pressure and that the [illegible]
to 100 pe [illegible]
the navi [illegible]
30,000 ft to the hangar apron was 16 min. The navigator did not respond at any time during the descent. At 5000 ft the pilot heard gurgling sounds over the intercom. and these continued until the canopy was opened. The

aircraft was met by a medical officer, who found the navigator was not breathing, was unconscious and deeply cyanosed. The mask was filled with vomitus. He started to breathe when the mask was removed and his colour improved but he remained cyanosed even on portable oxygen.

In hospital he was deeply unconscious during the first 4 hr; he had multiple convulsions. The pupils were widely dilated and he had up-going toes. His convulsions ceased; his coma gradually lightened, and he progressed towards consciousness during the next 8 hr. An X-ray of the chest showed some haziness of the right lower lobe but this cleared in two days. A blood sample, taken 12 hr after his removal from the aircraft, was later reported, by a reputable laboratory to have a haemoglobin of 17 3 per cent and of this 30 per cent was carboxyhaemoglobin. No other blood samples were sent for CO estimation so this isolated finding may be viewed with suspicion. He was seen by the RCAF Consultant in Medicine 14 hr after the incident. At this time he had a retrograde amnesia to about 4 hr before take-off. During the next few hours he remembered incidents up to the time of the take-off, but remained completely amnesic in regard to incidents from the take-off until he recovered consciousness 12 hr later.

Fourteen hours after the incident there were no abnormal findings in a very complete physical examination. The navigator was transferred to a large hospital where he was examined by a number of specialists Nothing abnormal was found. His mental state was considered to be normal. The EEG was quite normal. However, in view of the lengthy, almost moribund condition he was kept off flying for 6 months. He was then examined at the IAM. Nothing abnormal was found and his EEG was again quite normal. There was apparently no late mental sequelae of his prolonged, profound hypoxia and he was returned to full navigator duties.

The diagnosis and the aetiology are very doubtful. The aircraft oxygen system was checked and found normal. Admittedly his mask was filled with vomitus but presumably this occurred some minutes after loss of consciousness.

CASE 3

[illegible] during a rocket firing [illegible]

became worse, he experienced vertigo and was mildly nauseated. [illegible] difficult landing he was unsure of his equilibrium. His left side felt heavy and the floor came up to meet his left foot unexpectedly when walking. This condition spontaneously cleared in 3 hr. He was examined by the medical officer immediately after the landing He showed a 15° drift to the left. The caloric test with warm water was performed next day. Right ear—slight reaction, environment spun to right, nystagmus with fast component to left. Left ear—sudden violent response, environment spun to left, nystagmus with fast component to right. He became nauseated, very pale and collapsed. He recovered after one minute.

The significant findings in his past history are that he had a mild, similar attack, lasting a few hours, a year before when he was on pilot training.

This was accentuated by head turning. He was born with a torticollis. This was corrected by operation at age 4 years.

He was examined at the IAM two weeks later. He was found to have a mild neurotic element in his make-up, being restless and highly strung. At this time full otological audiometric and labyrinthine examinations showed nothing. He was found to be mildly susceptible to experimental motion sickness. His resting EEG showed sleep frequencies during overbreathing but was otherwise normal. The EEG was repeated on the accelerator. The resting record showed a well regulated 10 c/s alpha rhythm. Hyperventila-

for 5 sec without any slow waves Five G for 5 sec produced a period when he was probably unconscious and this unconsciousness was followed by slow waves. He then had a convulsion. The unconsciousness following the application of 5 G and the subsequent seizure can be considered normal since 40 per cent of subjects on this centrifuge have shown unconsciousness and seizures at high G loading. He was considered to have suffered a transient neuronitis and returned to full flying duties.

Case 4

He is a 27 year old pilot with 1800 hr flying time including 300 hr on jets. He was an average student but was unable to carry out a conversion course to operational interceptor flying. He was over-confident and made many mistakes in flying: he did not apparently recognize these mistakes. The question was raised of his willingness to fly. He was adamant in his desire to fly jets However, for safety, he was removed from operational training and transferred to a jet ferrying unit. He has made about 30 long range jet ferry flights but has had three incidents of diminished consciousness. The first occurred in June while flying in formation at 35,000 ft.

He had his normal breakfast of half a grapefruit, toast and coffee at 07 00 hrs. He had to fly as a passenger 100 miles to pick up the aircraft to be ferried and bring it back to his home base. He landed at 10.30 hrs, hurried to do shopping and go to the bank. He had a hurried lunch of a sandwich and coffee at noon and took off solo in a formation of three jet aircraft at 13.45 hrs.

directed into a convenient airfield where his oxygen system was checked and found correct He proceeded after one hour to his original destination. He had a slight headache. Medical examination at the destination revealed nothing abnormal. The oxygen system was again checked and found normal.

The second incident occurred in September. He had been taking an

antihistamine for allergic rhinitis but did not take this drug on the days he was flying. This morning he had a breakfast of one-half grapefruit, toast, a boiled egg and coffee at 07.00 hrs, and was flown 300 miles to pick up the aircraft. He had a lunch of a sandwich, piece of pie and a milk-shake at 12.30 hrs an dtook off for an intermediate base, where they landed. His hayfever (Ragweed) was extremely bothersome while he was on the ground but on take-off with 100 per cent oxygen, it rapidly cleared up. He was flying solo and No. 3 in a three place formation. They reached 42,000 ft (cabin altitude 26,000 ft) just above cloud. At 15.00 hrs, he felt light headed. He attempted to reduce his breathing rate because he had been warned of the dangers of hyperventilation after the first episode. He noticed that the two leading aircraft had disappeared into wispy cirrus clouds and he climbed to get above this. H e vision became blurred. The sun seemed very [illegible]

managed to land the aircraft at the destination. The other two pilots stated, emphatically, that there were no clouds whatsoever at the altitude they were flying. He was temporarily taken off flying until the end of October. (This is also the date of the end of the Ragweed seaton.)

At the end of October he was briefed to ferry a T33 to western Canada but was to be accompanied by an experienced pilot. The night before [illegible] of his young son. He had a [illegible]

and climbed to 35,000 ft (cabin 24,000). At 11.00 hrs he noticed the sun was very bright; he felt light headed; he was over-breathing and having some difficulty continuing his radio conversation with the Control. The safety pilot took over and returned to base. He states that the subject was having great difficulty talking to control and did not respond to his questions for at least 15 sec. He saw that the subject was very pale.

The subject was sent to the IAM where he was found perfectly able to pass all normal aircrew selection tests. He was psychologically fit for aircrew duties and showed no evidence of fear of flying. A resting EEG, at a blood sugar level of 80 mg per cent, showed a few random bisychronous sharp [illegible] area. The EEG was repeated [illegible] hyperventilation [illegible] 100 g of glucose was given. One hour later B.S. was 104 mg per cent. Three and a half G for 5 sec in the accelerator produced a few 3–4 c/s waves from the frontal region at the beginning of the acceleration. Two and one-half min of hyperventilation with 3·3 G for 5 sec applied at the end of this period produced high voltage bilaterally synchronous slow waves of 2–3 c/s lasting for 10 sec. Two and one-half hours after the glucose administration blood sugar was 77 mg per cent. The acceleration was again applied. No abnormality of the EEG was noted. A repetition of the H.V. for 2·5 min, with the acceleration applied at the end, gave a similar slow pattern lasting for 8 sec.

Because of the three episodes of diminished consciousness and the fact that his flying proficiency seems to be below the standards required for safety, he had been removed from flying duties.

Case 5

This 21 year old officer has a total of 400 hr flying time with 110 hr on jets. He was on an instrument training flight in a T33 at 26,000 ft (cabin 12,500 ft) He had a full breakfast including bacon and eggs, 3·5 hr before. He had been airborne for 10 min when he noticed "palpitation of his heart", followed by blurring of vision. His immediate action was to operate the "press to test" (he was on diluter-demand) take a deep breath and hold his breath. His symptoms disappeared in approximately one minute. He climbed to 30,000 ft when the symptoms recurred and he repeated the procedure. However, his symptoms did not improve and the instructor brought the aircraft down to 20,000 ft (cabin 10,000 ft). At this altitude his blurring of vision disappeared and the exercise was continued.

He was not unconscious but his blurring of vision was marked and the instructor had to take over. The aircraft and personal oxygen systems were

to 120/min. At two minutes he had blurring of vision and a heavy sensation in his head which he admitted he had also experienced at the time of the incident. The mechanism of this was carefully explained to him and he was returned to flying.

In view of his extreme susceptibility to hyperventilation, he was examined some three months later at the IAM. He had noticed that he had hyperventilated on a number of occasions but had been able to recognize the early onset of the symptoms and control his breathing rate. He had noticed that, while flying, his heart rate had often been very rapid The rate had increased quickly but not suddenly. The rapid pulse suddenly slowed. He did not believe he was hyperventilating during these attacks of rapid pulse but he could stop them by slowing his breathing. His physical examination showed

on the centrifuge did not increase the slow activity. After glucose feeding (B.S. 115 mg per cent) the combination of 3·1 G and hyperventilation produced only occasional delta waves.

He was further indoctrinated in the recognition of hyperventilation symptoms and told of the protective effect of high protein feedings. He was returned to full flying duties and has had no further trouble.

Case 6

An 18 year old NATO pilot trainee had flown 75 hr on Harvards. In

sensation all over his body; his vision became blurred and finally disappeared. Ten seconds later his vision returned and he found he was flying straight and level but 400 ft lower. He managed to land and reported the incident.

At the age of 11 he had had nephritis and during the convalescent period he had 4–5 fainting attacks per week. He states that even now he had one or two a week. The attacks always come after muscular effort however slight. He states that stretching himself after sitting for a while may precipitate an attack. The attacks always follow the same pattern of tingling sensation over the whole body with dimming of vision and perhaps complete loss of vision. On only one or two occasions has he lost consciousness, although at a few other times he has fallen and injured himself. He never experiences headaches either before or after the episode. There is no aura.

He was examined at the IAM and found fit for flying by all methods of medical examination used in assessing aircrew, except that there was a moderate degree of anxiety, not sufficient to warrant a psychiatric diagnosis. He had a completely normal EEG showing an alpha frequency of 10 c/s not changed by hyperventilation. The subject stated that he had described his attacks to the medical examiners. This is hard to believe and there is no record of it in either the original examinations in his own country, or on re-examination on arrival in Canada. In view of the danger associated with an episode of this type and the mild anxiety state, he was taken off flying and returned to his own country. No further news of him has been received

CASE 7

In April a 20 year old pilot trainee, with (75 hrs) flying time, was flying at 7000 ft in a Harvard when he had a momentary lapse of consciousness He had studied until midnight the night before and had overslept slightly but [illegible] toast, jam and a glass of milk at 07.00 [illegible]

thinks that the cold blast of air brought him around. He does not [illegible] he lost any height and did not travel far during his lapse of consciousness. He felt weak and very light as though he didn't weigh much. He sweated considerably. He did not have vertigo. He "just went back to the base in one straight line, came in and landed". He was examined immediately after landing. No abnormality was found.

He was re-examined at the IAM two weeks later and passed all aircrew physical examinations. He was at first thought to have become psychologically unsuitable for flying but further examination revealed that his apparent emotional coldness was due to early parental rejection. Despite a suggestion of emotional disturbance, he was considered not to have a psychopathic personality. His EEG was considered normal. This was [illegible] 3·0 G [illegible] the [illegible] cord [illegible] was rotating [illegible]

problematical. Blood sugar curves showed little rise or fall from the resting level.

He was returned to flying training and has since done well.

Case 8

A 25 year old NATO pilot had flown 200 hr of which 5·5 hr were on jets. He took off at 13·30 hrs in March in a T33, flying in the front seat with an instructor behind. He had an adequate lunch 2 hr before. He carried out aerobatic exercise for 1 hr. Finally the instructor demonstrated a cuban eight at a height of 14,000 ft (cabin 8000 ft). Following this manoeuvre the student was told to take control. The student related that he heard the instructor but was unable to make any voluntary movement; he did not

The instructor estimates that the student did not respond for 20 sec. However, the student recovered rapidly after this, took control and performed three or four "touch and go" landings before completing the exercise 30 min later.

EEG showed 3 c/s waves appearing early in hyperventilation and lasting 45 sec after H.V. ceased.

He was seen at the IAM three months later. He had had no further trouble and had progressed well in his flying training. Again he passed all standard aircrew medical examinations. The EEG was repeated. The resting and H.V. traces were essentially as found three months before. Three G on the accelerator produced no slow waves but coupled with 1 min

his flying training after further physiological indoctrination.

Discussion

In Case 1, it seems most likely that the navigator had not connected his oxygen hose and therefore became unconscious on the climb to 31,000 ft. If this explanation is incorrect, it is incredible that an experienced pilot should take an experienced navigator again to altitude and finish the further 30 min of the test flight. Case 2 presents great difficulty in diagnosis. He

became unconscious near the end of the climb to 30,000 ft and was near death when the aircraft had stopped rolling. The finding of 30 *per cent* carboxyhaemoglobin 12 hr after the incident is surprising. Carbon monoxide poisoning might have accounted for the rapid unconsciousness and its continuation for 12 hr. Against this, the pilot was also on diluter-demand and suffered no ill effects. Again, no carbon monoxide has been found in significant amounts in any of this type of aircraft. It is gratifying that this navigator was not only fit to return to full flying duties but was anxious to do so.

Case 3 was not unconscious nor did he have diminished consciousness but the vertigo due to the vestibular neuronitis was most distressing and occurring earlier in the rocket firing exercise might have been dangerous. He has had no recurrence. Even if he does, it is believed that he will now be able to detect the early symptoms and to land safely.

Case 4 shows the anxiety of the slightly overstressed pilot, the rush and hurry of pre-flight arrangements for family care, the hurried, inadequate high carbohydrate snacks before take-off, hyperventilation occurring before the incident and the incidents occurring some 3 hr after the snacks when the blood sugar was likely to be rebounding to a low level.

Case 5 has been labelled physiological. At the time of the incident, he was probably anxious as he was undergoing a check flight which was to be important in his career. He had a good meal some 3·5 hr before the incident but he was found to be extremely sensitive to the effects of hyperventilation. The EEG showed marked slow activity in the second minute of hyperventilation when the B.S. was 95 mg but the combination of 3·1 G on the accelerator and hyperventilation only produced a few slow waves when the B.S. was 115 mg per cent. It could not be proved that he had a paroxysmal tachycardia but he had a very labile pulse rate, a pulse rate which became very fast with hyperventilation. He is believed to satisfy the criteria and is labelled "physiological unconsciousness". He has been allowed to continue full flying duties.

Cases 6, 7 and 8 show a very similar pattern. They had been undergoing prolonged G and straightened out (Case 8 was still undergoing prolonged G). They could not have been hypoxic. It is significant that they were not experienced in this type of flying. In addition they were probably hungry. Anxiety was not definitely established in two cases but may well have been present. Two of the cases showed a normal EEG and this perhaps is against [illegible]". However, it is believed [illegible] ortance [illegible] l. [illegible] roduce a physiological unconsciousness in the subjects by the experimental means available. However since the stresses had only been applied singly it seemed essential to combine them. The accelerator was wired to allow six leads from scalp electrodes to be brought out through rhodium-plated slip rings to a Grass Model IIID Electroencephalogram. Useful EEG records with very little interference can now be taken Case 7 was the first individual given [illegible] hyperventilation. He did show a general- [illegible] he resting EEG. [illegible] ected to 3 G and

hyperventilation but with 3 G and no hyperventilation slow waves were not produced. A study of a number of aircrew (including these subjects), has been undertaken with this combined stress. It shows that the combination of the very minimal acceleration of 3 G for 5 sec together with hyperventilation and hypoglycaemia can produce unconsciousness lasting from 10–15 sec. This is felt to be a very important finding in the elucidation of these cases of physiological unsciousness. This work is to be reported elsewhere in May 1957.

That hypoglycaemia can cause unconsciousness has been shown by many workers. Moorhouse (1956) has recently discussed hypoglycaemia and reports on 15 patients who suffered sudden unconsciousness from this condition.[2] Four of these had major epileptic fits and three had deep, prolonged coma lasting for several days. In one of the latter cases, the coma resulted from post-gastrectomy hypoglycaemia. This is a finding which is giving us some concern, since we have a few pilots in the RCAF who are doing full flying duties after partial gastrectomy

Franks (1956) has discussed the significance of the EEG in the syndrome of physiological unconsciousness and reviewed the basic physiology underlying this syndrome[3,4] Beirman and Knight (1956) have described a condition of carotid sinus epilepsy.[5] None of our subjects have shown any sensitivity to bilateral massage of the carotid sinuses and therefore it is unlikely that their unconsciousness could have been produced by head movements with the neck restricted by tight clothing.

None of our subjects had markedly abnormal EEG's of the type usually associated with epileptics and it seems reasonable to assume that none of the cases in the present series is an epileptic However, in making this assumption, we acknowledge that it may be questioned. A subclinical epileptic may be triggered off by the combined stresses of hypoglycaemia, hyperventilation and the reduction of cerebral blood flow due to increased G A normal individual may become unconscious with the same stresses, but obviously not all normal individuals can become unconscious with reasonable levels of these stresses. The levels of the physiological variants which allow some normal individuals to react to the combined stresses is not known. The determination of these will required further investigation.

Summary

Eight cases of unconsciousness or diminished consciousness while flying were investigated at the IAM Toronto during 1956.

Five of these cases satisfied the criteria for the diagnosis of "physiological unconsciousness in medically fit aircrews".

The factors seem to be·

(I) Previous or concomitant G

(II) Hypoglycaemia occurring a few hours after a light carbohydrate meal.

(III) Hyperventilation

Also there seem to be associated:

(IV) Anxiety or anger.

(V) Early slow EEG activity with hyperventilation.

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In the IAM investigation of 1955, it had been found impossible to produce a physiological unconsciousness in the subjects by the experimental means available. However since the stresses had only been applied singly it seemed essential to combine them. The accelerator was wired to allow six leads from scalp electrodes to be brought out through rhodium-plated slip rings to a Grass Model IIID Electroencephalogram. Useful EEG records with very little interference can now be taken. Case 7 was the first individual given combined G, hypoglycaemia and hyperventilation. He did show a generalized slow activity at 3·0 G which was not present in the resting EEG. Case 1 showed a very startling unconsciousness when subjected to 3 G and

hyperventilation but with 3 G and no hyperventilation slow waves were not produced. A study of a number of aircrew (including these subjects), has been undertaken with this combined stress. It shows that the combination [illegible] May 1957.

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(V) Early slow EEG activity with hyperventilation.

Table I

Case	Month	Aircraft	Cabin Alt (ft)	Type of Flying	Prolonged G	
					Before	During
1	Oct.	CF100	31,000	Straight and level	No	No
2	Feb.	CF100	30,000	Straight and level	No	No
3	Mar.	Banshee	2000	Rocket firing	Yes	No
4 a	June	T33	25,000	Ferry flight	No	No
b	Sept.	T33	26,000	Ferry flight	No	No
c	Oct	T33	24,000	Ferry flight	No	No
5	June	T33	12,000	Inst. training	No	No
6	Dec. '55	Harvard	5000	Straight and level Previous aerobatics	Yes	No
7	Apr.	Harvard	7000	Straight and level Previous aerobatics	Yes	No
8	Mar	T33	8000	Prolonged aerobatics	Yes	Yes

Table II

Case	*Age*	*Total Flying Time*	*Jet Time*	*Solo*	*Experienced*	*Duration of Unconsciousness*	*Time of Day*	*G*	*H V*	*Hunger*	*Anger or Anxiety*
1	19	(hr) 400	200	Navigator	Yes	(sec) 60	16 00	No	No	No	No
2	20	400	200	Navigator	Yes	12 (hr)	19 00	No	No	No	No
3	22	600		Yes	Yes	Vision blurred	14 00	Yes	No	No	No
4 a	27	1800	400	Yes	Yes	20–25	15 00	No	? Yes	Yes	Yes
b				Yes	Yes	?	15 00	No	Yes	Yes	Yes
c				Yes	Yes	15	11 00	No	Yes	Yes	Yes
5	21	400	110	No	No	Vision blurred 60	10 30	No	? Yes	?	? Yes
6	18	75	Nil	Yes	No	10	15 30	Yes	No	? No	No
7	20	75	Nil	Yes	No	2–5	09 15	Yes	No	Yes	No
8	25	200	5–1/2	No	No	20	14 30	Yes	? Yes	Yes	Yes

Table III

Case	*EEG Resting*	*Centrifuge* (3G *for* 5 *sec of H V.*)	*Other Findings*	*Diagnosis*	*Disposition*
1	Slow with H.V	Slow waves, unconsciousness	Previous unconsciousness due to faulty O_2 regulator	Hypoxia ? non-connected O_2 hose	Full duties
2	N	N	30% COHb	Unknown	Full duties
3	N	Slow waves, unconsciousness at 5G	Previous attack 1 year before	Vestibular neuronitis	Full duties
4	Slow with H V.	Same pattern	Inadequate jet pilot	Physiological	Grounded
5	Slow with H.V.	Same pattern	Tachycardia	Physiological	Full duties
6	N	Not done	Many previous fainting attacks	? Physiological	Grounded
7	N	Slow waves	Nil	Physiological	Full duties
8	Slow with H V.	Same pattern	Systolic murmur	Physiological	Full duties

All these factors contribute to diminished cerebral activity and can summate. It is considered that this summation is the cause of the unconscious episodes and therefore these episodes may be prevented by removing one or more of the factors.

Sommaire

Huit cas de perte ou de diminution de connaissance en vol ont été étudiés à l'Institut de Médecine Aéronautique de Toronto en 1956. Ces cas présentent beaucoup d'analogie avec ceux qui ont été étudiés en 1955.

Dans cinq cas de la présente série le diagnostic de "perte de connaissance physiologique" a été posé. Ces cas présentaient le même schéma. L'incident survient quelques heures après un repas hydrocarboné léger. Dans trois cas, le sujet subissait ou avait subi des accélérations prolongées. L'anxiété et l'hyperventilation semblent avoir été en cause. Les individus furent trouvés "aptes" lors de l'examen selon les standards médicaux du Personnel Navigant de la R.C.A.F., mais la [illegible]

[illegible]

[illegible] *facteurs physiologiques tendant tous à provoquer une baisse du métabolisme cérébral se trouvent combinés. Pris isolément, ces facteurs ne sont pas nocifs, mais s'ils agissent tous ensemble, ils peuvent provoquer une perte de connaissance désastreuse.*

References

[1] Powell, T. J. "Episodic Unconsciousness in Pilots During Flight". *J. Aviat. Med.* 27, 301–16, 1956.

[2] Moorhouse, D. "Some Neurological Manifestations of Endogenous Hypoglycaemia". *Brit. med. J.* 2, 1512, 1956.

[3] Franks, W. R. "Notes on the Significance of EEG for Flying Personnel". Proceedings Eighth AGARD Aeromedical Panel Meeting May 1956.

[4] Franks, W. R. "The Summation of Physiological Factors Leading to Incidents in the Air". Proc. Eighth AGARD Aeromedical Panel Meeting May 1956.

[5] Behrman, S. and Knight, G. "Carotid Sinus Epilepsy and its Treatment by Denervation". *Brit. med. J.* 2, 1522, 1956.

LES PERTES DE CONNAISSANCE OCCULTES, CAUSES D'ACCIDENTS INEXPLIQUÉS

ANTOINE RÉMOND
Centre d'Expertise Médical du Personnel Navigant, Paris, France

DANS le domaine de la spécialité EEG, l'un des diagnostics les plus fréquemment demandés à la méthode est celui des pertes de connaissance. La question peut prendre plusieurs aspects. Tantôt l'accent est placé sur le diagnostic positif y a-t-il eu perte de connaissance, ou celle-ci peut elle avoir eu lieu étant donné le sujet considéré? Tantôt il est placé sur le diagnostic étiologique des pertes de connaissance. On désire alors rattacher celles-ci à une maladie déterminée, comme l'épilepsie par exemple, sans en discuter leur réalité.

C'est presque dans un cas sur deux que les malades sont adressés aux laboratoires d'électroencéphalographie avec une histoire de perte de connaissance La grande variété des cas pathologiques, les nuances importantes existant entre les sujets, ont pu nous donner une expérience approfondie de leurs différentes modalités. Chez les malades qui nous sont présentés certaines pertes de connaissance se sont révélées comme étant parfaitement occultes [illegible] le [illegible] in-*minée* ne pouvait manquer de faire naître dans notre esprit une association [illegible] merveil- [illegible] et logique [illegible] idents in-expliqués et pour lesquels l'enquête étiologique peut être devenue bien difficile quand le responsable de l'accident est mort. La présente communication n'apporte donc en rien les résultats d'une recherche à priori. Elle est seulement faite des considérations à postériori qui nous ont été suggérées par le titre du symposium qui nous réunit, étant donné nos très fréquents contacts avec le problème des pertes de connaissance, avec celui des troubles de la conscience et d'une façon plus générale ceux que posent les défaillances variées du système nerveux. Dans ce qui suit nous tiendrons très peu [illegible] elle-même nous commencerons notre développement par une [illegible] des pertes de connaissance occultes. Nous reprendrons ensuite d'une façon plus ou moins approfondie chacune des variétés proposées. Nous envisagerons enfin les moyens de dépistage et de prévention qu'il est possible d'envisager pour les éviter. Nous terminerons en évoquant certains problèmes

médico-légaux qui se rattachent à leur existence et qui se sont souvent posés à nous.

L'examen électroencéphalographique est un des moyens physiques d'introspection cérébrale utilisé en neurologie pour accroître les informations objectives récoltées par l'examen clinique classique. Il s'est développé de façon considérable dans les dix dernières années et son emploi pratique se trouve relativement bien codifié quoique avec des nuances méthodologiques importantes entre les différents centres utilisateurs.

Recueillant les variations de l'activité électrique du cerveau et les enregistrant d'une manière continue, l'avantage considérable de cet examen est son caractère dynamique et vivant. D'une part, il apporte des renseignements sur l'état de santé de base du système nerveux, d'autre part—il convient de bien insister sur ce point—il révèle les réactions du cerveau aux différentes contraintes auxquelles le sujet enregistré est soumis pendant l'enregistrement. Ces réponses, contemporaines des stimuli qui les provo-

dépistées puis étudiées au cours des dernières années.

L'étude des défaillances qu'il nous est donné d'observer dans notre pratique neuro-psychiâtrique et electroencéphalographique nous a permis de classer ces dernières en les rattachant à des modes de souffrance ou à des perturbations bien connues du système nerveux. Si notre connaissance a été acquise dans des milieux très divers, milieux hospitaliers variés (et en particulier dans le Laboratoire de Neurophysiologie clinique de la Salpêtrière), milieux de recherche ou d'expertise comme Le Laboratoire Médico-psychologique de la Prévention Routière et surtout le Laboratoire du Centre d'Examen Médical du Personnel Navigant de la région de Paris, nous avons pu recueillir dans ce dernier laboratoire des observations qui n'étaient en rien différentes de celles de nos autres centres d'activité. Les données acquises dans ces derniers ne faisant que préciser et compléter

(V)—enfin de coma à début brutal et imprévu.

Susceptibilité Sensorielle Anormale

qu'ils subissent.

Voici une observation récente recueillie au CEMPN de Paris qui illustrera [illegible]

Après avoir combattu en Indochine il revient au terme de son contrat A ce moment il a effectué sur réacteur plus de 700 h de vol de jour, et 23 h de vol de nuit. Il passe une visite d'admission comme pilote de ligne d'une Compagnie de transports aériens. Sa candidature n'est pas retenue pour des raisons qui ne nous sont pas expliquées mais qui semblent être en rapport avec l'existence d'un electroencéphalogramme anormal.

Après une période de repos ce jeune homme est envoyé au CEMPN de Paris en janvier 1956, pour une nouvelle expertise qui pourrait éventuellement lui ouvrir l'entrée d'autres compagnies aériennes. Au cours de sa visite il est reconnu normal à tous points de vue. En particulier un examen neurologique et un examen ophtalmologique classiques sont absolument normaux C'est alors qu'il nous est adressé au laboratoire d'électroencéphalographie. Son EEG spontané se situe dans les limites du normal; on note seulement d'importantes ondes lentes isolées postérieures, si fréquentes chez les adolescents. A la fin de l'enregistrement et selon notre protocole habituel, nous pratiquons une Stimulation Lumineuse Intermittente (S.L.I.) plaçant devant les yeux fermés du sujet un stroboscope à fréquence d' [illegible] 15/sec notre [illegible] s enregistrons

A la suite de cet incident le candidat est tout d'abord déclaré inapte pour un mois. De nouveaux tracés, faits avec beaucoup de précaution, montrant que l'état du sujet à l'égard des lumières papillotantes ne change pas, l'inaptitude définitive est prononcée en avril 1956. Il est radié du personnel navigant en octobre 1956

Depuis, nous avons suivi ce sujet de loin en loin et lui avons conseillé de prendre d'une façon habituelle un traitement anti-comitial convenable (à base de trimétadione) et de porter, pour se mettre à l'abri de façon relative, des verres filtrant la partie rouge du spectre lumineux Mais *J. G. . .* dans l'enthousiasme de sa jeunesse ne pouvait que difficilement accepter le contretemps qui brisait sa carrière et dont seul, à son point de vue, l'examen qu'on lui avait fait subir était responsable. Grâce à ses relations il fit tout pour retrouver une possibilité de voler. C'est ainsi que récemment il finit par être adressé en sur-expertise à un de nos collègues Marseillais dont les travaux sur l'épilepsie photogénique sont bien connus. Un electroencéphalogramme est à nouveau pratiqué La S.L.I. maniée normalement et sans précaution spéciale déclenche à nouveau et en quelques secondes une crise de Grand Mal à laquelle fait suite un coma de plus d'1/2 h

L'intérêt déjà considérable de cette observation s'accroît encore du fait de l'accident que nous avons pu sans doute éviter au sujet En effet, grâce aux relations de son père, *J. G. . .* était récemment en passe d'être engagé comme pilote par une compagnie employant des hélicoptères. C'est presque par hasard que le père nous mentionna ce fait à l'occasion d'une visite qu'il nous faisait pour nous faire signer une ordonnance. Nous avons

pu lui expliquer à temps le danger auquel il allait être exposé. Par une curieuse malchance notre infortuné pilote ne voulait rien moins que de placer ainsi au-dessus de sa tête un stroboscope de la plus grande taille. Il nous semble infiniment probable qu'au premier vol par temps ensoleillé l'appareil se serait écrasé avec à son bord un pilote inconscient en proie à une crise convulsive.

Des observations de ce genre ne sont pas rares La première en date que nous avons recueillie dans ce domaine il y a une dizaine d'années était celle d'un Ingénieur électronicien employé par un Fabricant de postes de télévision. Au moment où nous avons eu l'occasion de le voir il venait d'être placé par cette entreprise dans un service de contrôle où son occupation consistait à régler la synchronisation des bases de temps des télérécepteurs. Placé devant la source de lumière papillotante, véritable S.L.I. que constitue l'écran de réception, il avait été retrouvé à plusieurs reprises inanimé devant sa table de travail, la langue mordue, la bave aux levres, bref avec des stigmates fort nets de crise d'epilepsie récente.

A l'examen EEG sous S.L.I prudente, le sujet montrait de grandes décharges de pointe-ondes qui signaient le diagnostic d'épilepsie photogénique. Il a suffi à cet Ingénieur de ne plus régler de tubes à rayons cathodiques pour redevenir l'homme normal qu'il aurait pu ne jamais cesser d'être. Certes il ne conduisait pas d'avion mais sa compétence aurait fort bien pu le placer devant l'écran radar d'une tour de contrôle de terrain d'atterrissage. . .

Depuis 10 ans la littérature s'est progressivement enrichie d'un grand nombre d'observations du type suivant

Un individu se trouve dans une voiture qui roule au soleil couchant sur une route bordée d'arbres. Les tournants de la route sont tels qu'à un moment donné le soleil éclaire la voiture de côté Pour une raison quelconque le sujet est amené à tourner la tête du côté d'où vient la lumière. Cette lumière interrompue par les arbres du bord de la route, à une fréquence dépendant de la vitesse de la voiture, peut présenter 5 ou 6 interruptions/sec. Sans comprendre ce qui lui arrive l'individu présente quelques secousses myocloniques qui le projettent en arrière. Il perd connaissance et fait une crise de Grand Mal. Dans les observations de la littérature, un certain nombre de cas correspondent à celui du conducteur même de la voiture, dont la crise photogénique a naturellement été à l'origine d'un accident.

Tous ces cas d'épilepsie photogénique doivent être bien compris dans leur mécanisme. Ils font partie du groupe plus général des épilepsies Réflexes et des observations similaires quoique moins nombreuses ont pu être obtenues dans le domaine auditif (épilepsie phosphogénique et épilepsie musicogénique) et dans le domaine tactile. Il est possible qu'il en existe dans le domaine vestibulaire.

Tous les stimuli du milieu ambiant, qu'ils soient continus ou intermittents sont transmis pour information au système nerveux central par le jeu des récepteurs sensoriels Ceux-ci, en transmettant l'information aux structures capables de les percevoir, de les fixer et de les interpréter, rencontrent à l'intérieur du cerveau des circuits aux ramifications infinies en réseaux intriqués qui conduisent par ailleurs et sans cesse les messages de nature

électro-chimique qui permettent à chaque agrégat neuronique de l'encéphale d'être renseigné sur l'activité de tous les autres. Pour que ces messages soient utilisables pratiquement et ne contribuent pas à une cacophonie indéchiffrable, la nature a soigneusement utilisé le facteur temps pour éviter le mélange. Les techniques électroniques les plus récentes, celles qui utilisent la physique des impulsions, ont curieusement atteint à des mécanismes analogues à ceux utilisés depuis des millions d'années par les cerveaux animaux et humains. Mais ces circuits, qu'ils soient récepteurs, transmetteurs ou effecteurs sont sensibles à des degrés divers à des phénomènes de résonnance. C'est là une sorte d'artéfact nécessaire au principe même de leur fonction. La résonnance de ces conducteurs biologiques dépend non seulement de la configuration géométrique des circuits, mais bien plus encore de leur constitution chimique. Ils ont en effet à leur base une architecture savamment organisée de molécules d'une grande complexité dont tous les éléments, des plus abondants aux plus rares, sont utiles si ce n'est indispensables à la bonne tenue fonctionnelle de l'ensemble. Or l'électrophysiologie élémentaire a depuis longtemps montré les grandes modifications intervenant dans l'excitabilité des fibres nerveuses à la moindre perturbation, provoquée ou non, de leur contenu en certains ions comme le sodium, le potassium, le calcium . . . pour ne citer que ceux-là. Ce sont ces mêmes modifications de l'excitabilité ou ces différents états spontanés qui inter-

ont à la base de leur comportement un degré individuel d'excitabilité nerveuse, résultant à travers des lois fort complexes de l'excitabilité fragmentaire de l'ensemble des agrégats neuroniques dont leur S.N.C. est constitué. Il est des types de résonnance qui surviendront beaucoup plus tôt chez les sujets dont l'excitabilité de certains centres ou de certaines voies est telle que les conditions d'entrée en résonnance sont plus facilement réalisées.

Le cortex occipital dont une partie est le siège d'aboutissement des afférences visuelles, présente au repos une activité rythmique particulièrement spectaculaire et harmonieuse: le rythme alpha. Cette activité dont la fréquence est voisine de 10 c/s disparaît en grande partie à l'ouverture des yeux.

de façon rythmique

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relais thalamiques des voies visuelles et dans le cortex occipital. Les corps genouillés externes où s'opère la jonction entre les fibres présynaptiques et post-synaptiques, modulent suivant leur degré d'excitation le coefficient d'amplification affecté au message. Dans certains cas d'excitabilité anormalement élevée, le relais visuel agit dans les limites qui lui sont imparties par la structure comme un amplificateur puissant. L'effet de synchronisation et

d'entraînement apporté finalement au cortex optique peut devenir considérable et par son intermédiaire ou par celui de courts-circuits intra-thalamiques peut affecter de façon marquée l'activité électrique habituelle du reste du cerveau. De véritables décharges généralisées interviennent: c'est la crise d'épilepsie photogénique.

Parmi les individus dits normaux il est des sujets qui résistent bien aux stimuli visuels rythmiques D'autres au contraire y sont particulièrement sensibles et peuvent à chaque fois qu'ils les recontrent s'en trouver gênés d'une façon plus ou moins importante, éventuellement inconsciente. La sensibilité individuelle peut d'autre part varier dans de larges limites et être modifiée par certains facteurs métaboliques.

Dès qu'une susceptibilité sensorielle anormale (visuelle) est suspectée, on peut tenter d'en établir le diagnostic par les manifestations électrographiques spontanées ou provoquées qui correspondent à cette sensibilité Sur l'électroencéphalogramme spontané on pourra dans certains cas relever l'existence de pointe-ondes isolés sporadiques frontaux bilatéraux. C'est l'éventualité la plus rare. Ces décharges pourront parfois apparaître seulement au moment de la fermeture des yeux. Mais le plus souvent, il n'existe aucune manifestation spontanée de cette sensibilité et il faut avoir recours à la S.L.I. Celle-ci est effectuée à l'aide d'un stroboscope médical fournissant des éclairs à une fréquence de 1 à 100/sec. Les fréquences de 5 à 25/sec sont les plus efficaces. La fréquence de 15/sec correspond nettement à un maximum. Cette Stimulation Lumineuse Intermittente doit s'effectuer selon un protocole bien établi comme il en existe maintenant dans tous les laboratoires d'électroencéphalographie. Les décharges de l'épilepsie photogénique sont habituellement des polypointe-ondes ou des pointe-ondes en série rythmique à 3/sec apparaissant sur les régions frontales et de façon symétrique. (Dans le premier cas elles peuvent être accompagnées cliniquement de myoclonies.) Ces décharges se produisent le plus souvent aussitôt après [illegible]

survenue d'une décharge typique, le diagnostic reste formel Il existe une sensibilité sensorielle anormale. Celle-ci le moment venu pourra être à l'origine d'une crise d'Epilepsie photogénique.

Epilepsie Psycho-motrice

Les épilepsies psycho-motrices sont longtemps restées mal connues, placées de façon imprécise dans le grand cadre des Equivalents épileptiques Au cours des dix dernières années la délimitation d'une épilepsie électrique temporale a jeté beaucoup de lumière sur ce groupe des épilepsies psychomotrices dont 2 ou 3 autres variétés, correspondant à l'intervention de certains ensembles de structures nerveuses différents sont maintenant acceptées· l'épilepsie dite temporale étant la plus représentative. Comme on le maintenant fort bien, une des manifestations cliniques les plus habituelles et souvent isolée de cette maladie est une "fausse absence", beaucoup plus

longue que la crise de Petit Mal, pendant laquelle le sujet poursuit de façon assez coordonnée mais le plus souvent complètement inconsciente et automatique l'activité dans laquelle il se trouvait engagé. D'autres fois il présente à ce moment une activité tout à fait inadaptée au milieu ambiant et qui rappelle volontiers un comportement de recherche. A côté des fausses absences complètement inconscientes, et de diagnostic clinique relativement aisé à condition qu'elles soient observées par l'entourage, des manifestations voisines ne suppriment pas complètement la conscience mais l'altèrent suffisamment pour être à l'origine d'un véritable trouble paroxystique du comportement aux réalisations les plus variées.

Les épilepsies psycho-motrices ne sont pas rares bien au contraire. Il semble, maintenant qu'on les reconnaît plus facilement grâce à l'électro-encéphalographie, qu'elles sont en fait la variété la plus fréquente d'*épilepsie de l'adulte*. Elles ne constituent pas une épilepsie essentielle comme le Petit Mal, mais sont généralement secondaires à une lésion bien localisée du système nerveux comme peuvent en réaliser les si multiples agressions de la vie moderne. Celles produites par les traumatismes crâniens n'en sont qu'un exemple fréquent. Dans un assez grand nombre de cas elles restent longtemps méconnues, pouvant ne se manifester que dans certaines circonstances favorisantes qui activent les déclenchements de leurs paroxysmes. Si leur diagnostic clinique est parfois difficile, (les automatismes psycho-moteurs même quand ils sont durables sont souvent peu remarquables aussi bien pour l'entourage que pour le malade) leur diagnostic électroencéphalographique intercritique est le plus souvent aisé. Au niveau d'une ou des deux régions temporales ou fronto-temporales on recueille, soit des activités électriques caractéristiques comme des pointe-ondes isolés sporadiques plus ou moins dégradés, soit des signes de souffrance locale, moins évocateurs mais beaucoup plus permanents, comme un rythme thêta lent de 4 à 5 c/s étroitement localisé, asymétrique. Ce n'est que rarement, et dans les cas où l'agression causale plus importante aurait déjà fait suspecter l'existence d'une lésion du système nerveux, que l'on trouvera des manifestations plus graves comme un rythme delta polymorphe ou un rythme delta à front raide En dehors des cas où l'épilepsie est provoquée par une lésion organique du système nerveux, des manifestations cliniques ou même électriques similaires peuvent être produites par des perturbations métaboliques plus ou moins passagères telles que peuvent en réaliser par exemple une hypoglycémie accusée, une hypocalcémie marquée, etc.

Avant de quitter ce chapitre, rapportons l'observation typique du malade qu'un de nos maîtres, le Docteur Behague, nous adressa pour complément d'expertise. Ce malade, gardien de la paix, âgé de 38 ans, faisait partie d'une équipe de Football. En septembre 1954 il était désigné pour prendre part à un match et conduisant sa voiture, il amenait sa famille au terrain de sport situé à 4 km de son domicile A peine parti, au grand étonnement de ses passagers, il prit un tout autre chemin que le chemin habituel. Sa femme lui fit alors remarquer qu'il ne suivait pas la direction voulue mais, loin de lui répondre, le sujet restait muet et manifestement ne comprenait rien de ce qu'on lui disait. Il continuait à conduire avec habileté malgré les hurlements de terreur de la voiturée. Il évita même paraît-il un accident qui aurait pu être provoqué par la faute d'un autre automobiliste mais

il n'y eut pas moyen de le faire changer de chemin ou de le faire stopper. Ce n'est que lorsque la provision d'essence fut épuisée une demi-heure plus tard que le véhicule s'arrêta Le conducteur en descendit mais il tomba aussitôt sur le sol et ne reprit conscience qu'une heure après, à l'hôpital. A ce moment il avait un violent mal de tête et se trouvait très fatigué. Néanmoins il regagna son domicile et vint consulter le lendemain.

Dans les antécédents il fut possible de retrouver quelques absences retrouvées par les proches, mais elles étaient qualifiées de "distractions". Cliniquement le sujet ne présentait aucun symptôme de lésion objective du cerveau mais l'EEG montra de manière spontanée des décharges paroxystiques du type Petit Mal Myoclonique fort proches de celles de l'epilepsie photogénique. De plus il existait un foyer de pointe-ondes isolés dans la région temporale droite. Le Docteur Behague mit le sujet en traitement et celui-ci ayant repris son service de gardien de la paix n'a plus présenté semble-t-il de nouvelles crises psycho-motrices qu'elles soient de courte ou de longue durée Malgré les conseils qui lui furent prodigués le sujet conduit à nouveau son véhicule personnel.

Les Syncopes

Les syncopes sont des accidents banaux connus depuis fort longtemps en Médecine Générale et en Cardiologie. Ce n'est que depuis peu qu'elles ont intéressé les électroencéphalographistes et les spécialistes du système

gramme D'autres enregistrements physiologiques comme celui de la respiration, de la résistance cutanée de la peau, y sont aussi de plus en plus souvent ajoutés. Nos collègues ont pu ainsi reconnaître les modifications de l'activité électrique du cerveau au cours des syncopes et étudier celles-ci en fonction de la modification de l'EKG Ils ont trouvé un outil des plus précieux qui leur a permis dans bien des cas de redresser un faux diagnostic de comitialité pour porter celui de crise lipothymique.

La défaillance paroxystique du système nerveux qui constitue le terme ultime de la syncope se trouve généralement sous la dépendance d'un arrêt cardiaque A son tour celui-ci peut n'être qu'un phénomène réflexe provoqué par une excitation vagale suffisamment importante ou suffisamment durable. Sans présenter pour autant de lésions du système nerveux ou de maladie vasculaire, une grande proportion des sujets dits normaux d'une population moyenne est plus ou moins prédisposee aux manifestations syncopales. Dans la vie des individus celles-ci sont infiniment plus fréquentes que les manifestations épileptiques. En fait, il est peu de sujets qui, au moins une fois dans leur vie, parfois plus souvent et principalement au cours de leur adolescence, ne se sont évanouis Ces évanouissements ne sont jamais spontanés. Ils dépendent toujours de la stimulation vagale que peut provoquer le milieu intérieur (surtout l'état digestif du sujet) ou le milieu ambiant l'atmosphère chaude et confinée, la station debout prolongée, l'émotion, la vue du sang, la douleur, la peur et l'anxiété sont des éléments

favorisants habituels d'efficacité bien connus. Au laboratoire il n'est pas rare d'enregistrer des syncopes. L'on en enregistre plus souvent que des crises d'épilepsie. Le tracé électroencéphalographique caractéristique, fait d'ondes lentes généralisées à fréquence progressivement ralentie et d'amplitude progressivement augmentée, survient généralement après un arrêt de l'electrocardiogramme ayant duré plus de 4 à 6 sec. Dans ce cas le diagnostic nosologique de la *P. C.* est facile. Il est moins immédiat quand l'EKG, ne s'étant pas interrompu, la syncope est intervenue sous l'influence d'une *dépression tensionnelle suffisante. La pâleur, la sudation, les nausées parfois* suivies de vomissements, en sont alors des signes concomitants fort utiles. Quand le diagnostic a besoin d'être confirmé, il est possible de provoquer la syncope ou tout au moins ses signes électriques avant-coureurs par la simple compression oculaire.

Sommeil

Le sommeil paroxystique et les endormissements invincibles doivent rentrer dans le cadre de notre étude étant donné les multiples observations de ce *type que nous avons recueillies au Centre d'Examen du Personnel Navigant.* Il ne s'agit pas là de narcolepsie, cette maladie étant habituellement parfaitement connue du sujet qui en est atteint. Il s'agit seulement d'un phénomène très voisin de l'induction physiologique naturelle du sommeil chez les individus fatigués. Tous les conducteurs d'automobiles connaissent bien la lutte qu'ils doivent mener occasionnellement contre l'endormissement, en particulier quand après de longues heures de conduite il leur arrive de faire une légère collation. Cette éventualité étant plus fréquente encore quand la voiture est chauffée.

*Un certain nombre de sujets qui nous sont adressés pour examen systé*matique sont enregistrés au début de l'après-midi. Après quelques minutes d'enregistrement les yeux fermés, situation habituelle à l'examen EEG ayant pour but de maintenir le système nerveux au repos, ils présentent des signes électriques plus ou moins évidents d'endormissement. Dans cette période initiale, le moindre bruit inattendu provoque une réaction d'éveil qui ramène l'activité électrique typique de l'état de veille et qui aide d'ailleurs par son contraste à faire rattacher au sommeil les modifications précédentes du tracé. Mais c'est souvent pour peu de temps que le réveil *intervient et quelques secondes après son début*, le tracé montre à nouveau l'effondrement progressif du niveau de conscience. Les stimuli divers sont de moins en moins efficaces et le sujet finit par dormir profondément.

Chaque fois que dans notre laboratoire un sujet se présente de cette [illegible]

parfaitement normal, c'est-à-dire ne plus montrer de signes d'endormissement. Mais par contre, certains sujets, même placés dans des conditions favorables, s'endorment à nouveau quelques minutes après qu'on leur ait fait fermer les yeux. Il est naturellement difficile de tracer les limites, dans ce domaine, d'une induction trop facile du sommeil, entre ce qui est normal

et ce qui est pathologique. Mais étant donné les grands dangers que peut provoquer l'endormissement involontaire et invincible, nous avons pris l'habitude de considérer comme probablement inapte tout sujet qui montrait le même tendance au sommeil au cours de tracés répétés, ceux-ci étant faits, à part l'occlusion des yeux, dans des conditions particulièrement peu favorables à l'endormissement

Comas

La cinquième catégorie de *P. C.*, celle des comas à début brutal et imprévu, comme celle de l'endormissement invincible, se trouve un peu en marge des trois premières du fait de sa fréquence moins grande. Il n'en est pas moins vrai que, là aussi, il nous a été donné de recueillir plusieurs observations qui correspondent à ce groupe. C'est par exemple le cas suggestif d'un autre malade que le Docteur Behague nous envoyait pour expertise electroencéphalographique.

Ce sujet de 56 ans conduisait en plein jour une automobile et traversait une importante agglomération de la région parisienne lorsque sans raison apparente il n'évita pas un bicycliste qui suivait le même chemin que lui. Le choc fut assez violent pour non seulement jeter sur le sol le cycliste qui fut gravement blessé, mais aussi pour détériorer l'automobile dont une aile fut fortement cabossée et dont un phare vola en éclats Malgré cela la voiture continua son chemin, évitant les passants qui tentaient de l'arrêter. Après avoir secouru le cycliste, les agents de police à tout hasard suivirent le chemin de l'automobiliste et trouvèrent la voiture arrêtée 1 km 1/2 plus loin. Le conducteur était resté assis à son volant, mais lorsque les agents lui demandèrent ses papiers il fut incapable de dire ni son nom ni son adresse. Toutes ses réponses étaient lentes et le sujet hébété fut considéré par eux comme étant en état d'ivresse Comme il y avait délit de fuite il fut arrêté. Quoique le sujet semblât en fait dans un état anormal assez différent de l'ivresse on lui fit une prise de sang, après qu'il l'ait apparemment acceptée. Elle montra un taux d'alcool sanguin très bas excluant l'intoxication alcoolique Sur ces constatations on ne délivra pas de mandat d'arrêt et l'on fit conduire le sujet dans un hôpital où le Docteur Behague fut affecté pour préciser sa responsabilité. A l'examen il le trouva confus, hébété, ne répondant que [illegible]

[illegible] qu'elle est Directrice d'Ecole D'une façon manifeste il s'agissait d'une aphasie. L'électroencéphalogramme que nous pratiquâmes alors mit en évidence des altérations hémisphériques gauches considérables à maximum fronto-temporal sous forme d'ondes delta irrégulières permanentes. Ces [illegible] parfaitement

L'enquête révéla alors que 2 mois avant cet épisode le sujet avait eu un premier accident. Depuis celui-ci il avait souvent paru "tout drôle" et "bien changé" à son entourage et surtout dans les derniers temps Il est donc

vraisemblable que l'hématome sous-dural découvert à la suite de l'accident qui a provoqué notre examen datait du traumatisme que le sujet avait subi 2 mois plus tôt.

A ce cas d'hématome intra-crânien nous pouvons, du fait de son origine vasculaire, rattacher le cas d'un Navigant qui au volant de sa voiture se sentit tout d'un coup dans un état bizarre dans lequel il avait la sensation de ne plus percevoir les objets comme d'habitude, à tel point qu'il éprouva le besoin de s'arrêter. Bien qu'il eut décidé de repartir après quelques minutes, on s'aperçut à l'occasion d'un examen médical peu de temps après, qu'il présentait une hémianopsie latérale homonyme en quadrant inférieur dont le début semblait coïncider avec la survenue brutale de sa difficulté de conduite L'étiologie de ce cas n'est pas expliquée mais l'Electroencéphalogramme montrait et montre encore de grosses anomalies fonctionnelles de la région occipitale correspondante. Une lésion vasculaire de cette région est vraisemblable.

Pour donner un exemple un peu différent nous avons recueilli un véritable tracé de coma chez un homme parfaitement éveillé répondant aux questions mais que sa femme avait trouvé depuis quelques jour suffisamment différent dans son comportement habituel pour l'amener consulter. Lui-même s'il ne confirmait en rien l'anomalie de son état. tombait dans un coma clinique profond le lendemain du jour où nous l'avons examiné. Ce coma dura plusieurs jours et ne céda qu'à une thérapeutique intensive pratiquée dès que le diagnostic étiologique de coma hépatique put être établi. Ces exemples divers pourraient être multipliés en grand nombre mais tous ont un caractère exceptionnel qui diminue sans doute l'intérêt de leur groupement.

Dépistage

Quoique les différentes catégories de pertes de connaissance que nous venons de passer en revue soient d'un aspect assez disparate, elles gardent entre elles le caractère commun de constituer une défaillance imprévue du système nerveux prenant l'individu tout à fait au dépourvu. Quand ces défaillances se répètent et que ceux qui les subissent reconnaissent l'existence d'un trouble paroxystique de leur état de conscience, ils provoquent généralement d'eux-mêmes les examens qui permettent de faire le diagnostic et d'établir l'étiologie Cependant, dans un certain nombre de cas, la première défaillance survient en service et peut être à l'origine de conséquences dramatiques. Il importe donc d'avoir, devant les possibilités d'occurence de ces manifestations dangereuses de la fragilité du système nerveux, une attitude précise tendant à dépister ces cas quand il y a eu accident ou à les prévenir avant toutes anomalies graves dans le comportement des individus

Pour effectuer ce dépistage il importe de faire pratiquer un examen neurologique détaillé et surtout un examen électroencéphalographique inquisiteur à toute personne ayant présenté au cours de son travail ou de l'une de ses missions une attitude quelque peu suspecte pouvant être interprétée comme une modification transitoire mais inquiétante de l'état de conscience. D'une façon spéciale et obligatoire tous les individus ayant présenté en service ou hors de service un accident quelconque et à fortiori

un traumatisme crânien seront examinés très soigneusement:

(I)—à la recherche d'une origine cérébrale méconnue de l'accident,

(II)—à la recherche des conséquences cérébrales de celui-ci pouvant entraîner à l'avenir certaines défaillances locales ou généralisées du système nerveux. En France les consultations de Neurologie et les Laboratoires d'Electroencéphalographie dont sont dotés les Centres d'Examens Médicaux du Personnel Navigant sont parfaitement équipés pour pratiquer ces expertises à la demande.

PREVENTION

En fait, c'est moins le dépistage des causes d'accidents passés et l'étude des personnels que l'on suspecte d'avoir perdu connaissance qu'il importe d'organiser, qu'une véritable prévention de ces défaillances du système nerveux par un programme étendu de recherche et d'amélioration des facteurs de sécurité dans la sélection du personnel. Ce problème de la prévention doit être considéré sous deux aspects très différents à la fois administratif et technique.

S'il est permis de faire des recommandations, en vue de sa solution il semble que l'on ne saurait trop conseiller de pratiquer systématiquement un examen electroencéphalographique standard suffisant, c'est-à-dire d'une technique convenable et comportant des activations mineures, au moment de la visite d'admission des candidats pilotes, à l'entrée des élèves dans les Écoles de l'Air, et d'une manière plus générale à toutes les personnes destinées à un poste dont la responsabilité se colore d'un problème personnel ou général de sécurité. Ce premier examen systématique à l'entrée permettrait de décourager avant qu'elles n'aient fait un sacrifice durable pour leur entraînement, toutes les personnes présentant une épilepsie essentielle méconnue c'est-à-dire n'étant pas encore entrée dans la phase clinique mais se manifestant malgré tout par des altérations électroencéphalographiques caractéristiques. Un individu sur deux cents se trouve dans ce cas. L'éliminer à temps ne peut manquer de représenter pour lui et pour l'Etat une économie importante. C'est par le même examen que l'on pourrait écarter une partie des sujets présentant une susceptibilité sensorielle anormale surtout et tout au moins dans le domaine lumineux.

Les candidats dont l'histoire révèlerait des antécédents inquiétants comme une anoxie à la naissance, une mise au monde à l'aide de forceps, un traumatisme crânien, une maladie à contexte encéphalopathique possible, une tendance lipothymique, devraient sans doute être soumis à un examen électroencéphalographique plus rigoureux que l'examen standard. Cet examen devrait être pratiqué pendant que les sujets seraient soumis à celles des contraintes de leur vie professionnelle qui seront les plus fréquentes ou les plus dangereuses. Ce test, pour être satisfaisant, devrait même chercher à reproduire le groupement simultané de ces contraintes dont l'expérience a pu montrer le pouvoir de gêne le plus grand, ainsi on pourrait établir de façon routinière autour des enregistrements électriques, le moyen de placer les individus dans des conditions d'hypoxie modérée, de chaleur et de confinement anormal, de dépression barométrique limitée, d'accélération etc. On devra aussi les soumettre à des stimulations lumineuses ou sonores telles que celles susceptibles de déterminer une crise d'épilepsie

réflexe chez les prédisposés. On pourra enfin les examiner dans des conditions physiologiques un peu inusuelles comme celles que *provoquent* l'hypoglycémie, l'hyperventilation, l'ingestion d'alcool, l'abstention de sommeil etc. . . . chaque fois que l'on saura *que l'un de ces facteurs* est d'importance pour le sujet en cause.

Par l'intermédiaire de cet examen on *se comporterait* avec ces hommes appelés á de grandes responsabilités et dont les défaillances peuvent entraîner des accidents catastrophiques, *comme* l'*Ingénieur se* comporte devant un matériau qui doit entrer dans la construction d'un avion et dont la résistance dans *certaines conditions détermine le sécurité* de l'ensemble. On ne voit pas en effet pourquoi l'on serait tellement moins exigeant pour les hommes *que pour les matériaux* quand *la* vie même des hommes est en cause. Le personnel exposé doit être éprouvé en vue de sa résistance aux perturbations physiologiques que la situation dans laquelle on le place est susceptible de provoquer. Non seulement sa résistance doit être éprouvée mais il semble, puisque l'on parle de sécurité, qu'il devrait disposer comme la machine qu'il conduit d'un certain " coefficient de sécurité." C'est cette attitude qui, à notre sens, devrait présider à l'élaboration d'un protocole d'examen electroencéphalographique du deuxième degré, véritable banc d'essai du système nerveux humain. C'est à un pareil examen que l'on soumettrait aussi les pilotes d'avion léger ou d'avion à moteur qui doivent être transférés sur avion à réaction ou sur des engins exigeant des qualités particulières de ceux qui les conduisent.

La pratique des examens EEG spéciaux et la régularité des examens médicaux actuellement pratiqués permettraient sans doute d'éviter une proportion importante de défaillances dangereuses Naturellement certaines d'entre elles, dues à la coincidence exceptionnelle de facteurs imprévus, ne pourront être prévenues. C'est pour certains de ces cas qu'une sorte d'indicateur de la panne humaine, sous forme de dispositif d'alarme pourrait certainement être employé. Les décharges paroxystiques de l'épilepsie, le rythme thêta ample et étendu du dé [illegible] les signes électriques de l'endormissement, [illegible] et filtrés peuvent déclencher la mise [illegible] signalant le danger à l'entourage. Depuis quelques années on utilise sur ce principe un appareillage de servocontrôle d'anesthésie qui dose automatiquement les substances hypnogènes pour conserver au sujet une profondeur de sommeil qu' ajustent ses propres ondes cérébrales.

Pour les cas de syncope, les signes EEG et EKG pourront provoquer un stimulus sensoriel intense ou un électro-choc transthoracique à déclenchement automatique comme celui qui a été mis au point pour empêcher de mourir les malades susceptibles d'arrêt cardiaque (maladie de Stokes-Adam). Dans le cas de l'endormissement un stimulus sensoriel intense pourrait se charger de réveiller le dormeur en même temps que son endormissement ayant été signalé à sa base par radio on pourrait lui faire donner l'ordre de rentrer immédiatement.

Problèmes, Médico-légaux

A côté de l'aspect diagnostique et nosologique des *P.C.* occultes, à côté aussi des problèmes de leur dépistage et de leur prévention chez les

personnels navigants, leur constatation effective ou la prévision de leur possibilité par un examen EEG n'est pas sans poser certains problèmes médico-légaux.

(I) Un examen EEG peut-il légalement suffire à faire prononcer l'inaptitude au vol d'un individu?

(II) Ses conclusions sont-elles scientifiquement valables?

(III) Comment doit-on envisager son emploi habituel pour réserver au maximum l'avenir des individus qu'il peut éliminer?

(I)—Dans la législation française, l'arrêté du 13 novembre 1953 fixant les conditions d'aptitude physique et mentale aux Brevet, Licence et Qualification du Personnel Navigant de l'Aéronautique civile stipule. "Le candidat ne présentera pas dans ses antécédents de troubles nerveux importants. Il ne présentera aucune affection évolutive ou non évolutive du système nerveux dont les effets pourraient compromettre la sureté de manoeuvre d'un avion, aucun trouble mental ou signe laissant présumer une epilepsie latente."

Cet arrêté ne précisant pas le moyen par lequel le diagnostic d'une affection évolutive ou non du système nerveux ou celui d'une épilepsie latente doit être pratiqué, il n'y a aucun doute que rien ne s'oppose à ce qu'une conclusion dans ce domaine puisse être obtenue, au moins en partie, à l'aide d'un examen EEG. La difficulté reside en réalité de ce que ce genre de conclusion vient plus souvent de l'examen EEG que de l'examen neurologique lui-même. Si un pareil fait ne doit pas étonner, quand on pense à l'énorme différence de capacité de résolution entre les deux examens clinique et électrique à cause de l'amplification considérable que ce dernier tient à sa disposition la question se pose alors de savoir si les signes sur lesquels se base le diagnostic electroencéphalographique sont aussi valables que les signes cliniques.

(II)—L'Electroencéphalographie est certes une discipline récente. Sa complexité, sa base instrumentale encombrante, font qu'elle est loin d'être appliquée partout ou par tous avec une efficacité semblable et une égale maîtrise. Mais dans les Centres neurologiques, neuropsychiâtriques et neurochirurgicaux où elle se trouve en confrontation permanente avec les résultats de l'examen clinique et ceux des autres examens complémentaires elle a gagné une sureté au moins aussi grande que tous les autres moyens et une éloquence probablement plus fréquente

Des incertitudes cependant subsistent dans le domaine de l'EEG comme dans les autres domaines diagnostiques sur la signification que l'on doit attacher à certains signes encore trop peu étudiés, ou trop peu fréquemment rencontrés. Ces hésitations sont exploitées par les opposants de la méthode. Aussi devra-t-on agir avec d'autant plus de prudence dans le choix des critères, dans la définition de la séméiologie électrique à partir de laquelle un diagnostic impliquant l'inaptitude au vol peut être porté.

Ces critères étant choisis, les définitions séméiologiques arrêtées, il importerait de les publier et de les utiliser comme une sorte de règlement pour qu'avec toutes les précautions nécessaires on puisse prendre la même attitude dans des cas comparables, à des endroits et à des époques différentes.

Certaines observations actuelles du CEMPN soulignent l'urgence d'une pareille attitude. Certains pilotes pour lesquels "l'arrêt d'inaptitude" a été conseillé à la suite d'un EEG suffisamment anormal ont été, espérant les divergences de vue des spécialistes, consulter ceux-ci en série. La conclusion de ces derniers, insuffisamment informés du problème et ne tenant pas compte de l'utilisation que leur client pouvait en faire, ne donne pas le même accent de gravité aux mêmes manifestations électriques. Un foyer d'épilepsie temporale par exemple tellement commun dans la pratique peut être considéré comme bénin quand on est certain que sa cause n'est pas une tumeur cérébrale mais une cicatrice. Les intéressés ayant en main des comptes-rendus d'examen contradictoires, au moins en apparence, font appel au Conseil Médical du SGACC pour faire reconsidérer la décision qui a pu les faire suspendre ou rayer du personnel navigant.

(III)—Quand un navigant en pleine santé apparente, ayant fourni les preuves de son habileté par de nombreuses heures de service et des années d'entraînement, se trouve arrêté brusquement dans sa carrière par les conclusions d'un examen qu'il a pu passer pour des raisons fortuites, il est bien naturel qu'il exprime son ressentiment et qu'il cherche à acquérir l'assurance que le geste par lequel on arrête sa progression est motivé.

Si l'on ne doit pas pour autant se passer des possibilités diagnostiques considérables de l'EEG dans le domaine des lesions du système nerveux, l'on devra organiser son utilisation de telle sorte qu'un individu qui présente une tare occulte puisse être éliminé avant même son entrée dans le personnel navigant et non pas comme le pilote qui fait l'objet de notre première observation après six ans d'entraînement et de succès.

SUMMARY

During the last ten years it has become possible to reclassify the different categories of paroxysmal failure of the adult nervous system This has been brought about by routine use of the EEG examination in great numbers of subjects involving individual responsibility for collective safety (e.g. railroads, public transport, aircrew, etc.). These episodes, though unrecognized by the subject and his associates, are sometimes fortuitously discovered during laboratory examinations under [illegible] *therefore to* [illegible]

The study of fainting episodes observed in subjects who were [illegible] *their occurrence has resulted in their classification based on the well-known disturbances of the central nervous system. Our experiences have in fact enabled us to distinguish between different types of loss of consciousness due to the following causes*

(I) An abnormal sensory sensitivity (photogenic epilepsy and reflex epilepsies), when various stimuli are repeated at particular frequencies in subjects with hyperexcitability of certain sensory pathways

(II) Psychomotor epilepsy (spurious temporal absences; automatisms) occurring as a result of stress which causes the activation of a cerebral area whose resistance has been lowered by previous stress.

(III) Syncopes and lypothymia, in subjects with vagal hyperexcitability under

such predisposing conditions as hot and confined work space, muscular discomfort, suddenly eliminated arterial compression, acceleration, pain, emotional upset, etc.

(IV) Paroxysmal Sleep

(V) Paroxysmal coma concomitant with certain visceral diseases.

The possible occurrence of the above manifestations and the knowledge which we have been able to acquire concerning them urgently indicate the necessity for their systematic diagnosis and prevention. For instance, in flying personnel or ground crews whose jobs implicate great responsibilities, it is perfectly practicable to plan routine EEG examinations with minor stimulation (hyperpnea, S.L.I., oculo-cardiac reflex) as an initial selection procedure or to qualify them for special training. The Centre d'Expertise Médicale du Personnel Navigant (French Air Force Physical Examination Centre) is certainly well equipped to handle this. Such a systematic examination would immediately spot a great number of cases of abnormal sensory sensitivity of the reflex type and of unrecognized essential epilepsy. Outside of the induction or qualification period, a special examination will be given to those individuals who are subject to certain stresses This examination will simulate the particular stressful situation and will constitute an additional selection device. Finally, all subjects who have had any kind of accident in or out of the service and specially where head injury is involved, will be particularly carefully examined. Without exception, the following will be looked for

(I) A hidden cerebral cause of the accident

(II) Possible brain injuries resulting therefrom, which could portend certain local or generalized failures of the central nervous system.

As for preventive measures, besides the selection made possible by methodical diagnostic prodecures, they could be facilitated by using a warning device which would be easy to develop. This device would alert the other crew members of a dangerous functional impairment of the individual in a vital position It could even be useful for returning the subject to a normal state It would of course be based on a mechanism which produces an automatic counteraction set in motion by an abnormal electroencephalogram or electrocardiogram

II. UNEXPLAINED AIRCRAFT ACCIDENTS

SÉCURITÉ EN VOL ET ACCIDENTS AÉRIENS D'ORIGINE INDÉTERMINÉE DANS L'ARMÉE DE L'AIR FRANÇAISE

P. Bergeret et R. Marchesseau
Paris, France.

"—Sergent X . . . sur Ouragan. Au cours d'un vol d'entraînement en patrouille, après 35 min d'exercice à 10,000 m part en piqué et s'écrase au sol.

L'enquête ne peut aboutir à aucune conclusion sur les causes de l'accident."

"—Sergent Y, sur Mystère IV. Après 23 min de vol, à 15,000 m et 4 min après avoir signalé correctement sa position, s'écrase au sol.

Conclusion de l'enquête: Cause indéterminée".

Tel est, dans son dramatique laconisme, le type d'accident aérien dit inexpliqué, ou d'origine indéterminée qui, périodiquement, vient dans nos escadres poser son point d'interrogation. Il met à l'épreuve le moral des équipages, il constitue, pour les Hautes autorités de l'Aviation dans tous les pays, une préoccupation majeure et, pour les responsables de la sécurité en vol, un échec.

Se résigner, se consoler en disant que le vol à hautes performances sera toujours dangereux par définition, et "qu'on ne fait pas d'omelette sans casser des oeufs"—ce n'est pas une solution. Il faut travailler sans cesse à réduire la marge d'insécurité. C'est pourquoi nous avons vu avec intérêt le Panel Aéro-Médical inscrire à son programme ce problème d'actualité, dans l'espoir d'apporter, sur le plan international une contribution utile à la cause commune.

Certains, nous le savons, ont pu s'étonner et se demander s'il y avait vraiment là matière à discussion médicale. Nous pensons, quant à nous, qu'un médecin de l'Air ne doit pas se désintéresser d'une telle question, et cela pour deux raisons.

La première est d'ordre général. L'expérience a montré de façon indiscutable, depuis de longues années et dans toutes les aviations, que la grande majorité des accidents aériens (50 à 75 pour cent selon les statistiques), relève du *facteur humain*. Par extrapolation, on peut admettre que ce facteur joue également dans les accidents inexpliqués et cela avec une fréquence à peu près identique. Or, qui dit "facteur humain", qu'il s'agisse du physique ou du mental, justifie par là même l'intervention du médecin dans la recherche des causes—nous disons bien du médecin de l'Air, instruit des aspects spéciaux de son rôle, non du praticien qui se contente de soigner, mais du médecin qui partage intimement l'existence du pilote, s'intéresse à lui dans l'état de santé parfaite sans attendre la maladie, connaît ses réactions, reçoit ses confidences, et est ainsi à même d'apporter à l'enquête officielle des précisions extrêmement utiles.

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La deuxième raison est plus particulière: on a tendance, en face d'un accident pour lequel n'apparaît aucune autre explication, à l'attribuer à une "défaillance physique" du pilote; l'on met ainsi implicitement en cause la responsabilité médicale, soit du médecin qui a la charge du Personnel Navigant, soit de la médecine aéronautique qu'on a l'air de taxer d'insuffisance dans ses méthodes de sélection, de surveillance médicophysiologique et dans ses mesures prophylactiques—parfois si mal acceptées d'ailleurs par les exécutants eux-mêmes. Au médecin donc de montrer dans quelles conditions la défaillance physique ou mentale est probable ou seulement plausible, ou formellement invraisemblable, et à veiller à ne pas laisser déplacer, consciemment ou non, des responsabilités qui sont toujours lourdes.

Au demeurant, dans l'Armée de l'Air Française, l'effort soutenu depuis la deuxième guerre mondiale pour accroître la sécurité aérienne a porté ses fruits. La statistique montre que, de 1947 à 1956, la proportion d'accidents aériens *de toutes causes* a baissé progressivement, pour 10,000 h de vol, de 20 0 en 1947 à 5·4 en 1955 et 5·6 en 1956 (avec un court palier à 8·7 entre 1950 et 1952, date de l'entrée en service des chasseurs à réaction). Dans la même période, le taux des accidents mortels pour 10,000 h de vol s'est abaissé de 1·9 à 1·0. Quant aux taux *d'accidents d'origine indéterminée*, qui était de 0 8 en 1947, il n'était plus que de 0 2 en 1955 et de 0·48 en 1956 (après avoir atteint, en 1951 le taux de 0 9 pour la raison donnée ci-dessus).

Pendant ces huit dernières années, la moyenne des accidents d'origine indéterminée par rapport aux autres causes (personnel, matériel, diverses) se chiffre à 6·2. La situation apparaît donc comme plutôt favorable.* A quoi [illegible]

cerne le facteur humain, meilleure appréciation du comportement psychique [illegible]

valeur trop absolue. La définition de l'accident d'origine indéterminée n'est que négative, et c'est une rubrique élastique, dans laquelle on fait entrer des concepts assez différents.

Il y a, d'abord l'accident absolument *inexpliqué*, et inexplicable; l'avion a disparu en mer ou dans la forêt vierge, ou bien il a percuté le sol avec une telle violence ou a brûlé si complètement qu'aucune constatation matérielle n'est possible. Toutes les hypothèses sont permises—aucune n'est fondée.

Il y a d'autre part, l'accident où plusieurs causes sont probables et même certaines—mais leur intrication est telle que la Commission d'enquête ne se résoud pas à faire un choix et préfère rester dans l'incertitude. C'est cette catégorie d'accidents qui mériterait plus spécialement d'être dite "de cause indéterminée".

Il est enfin des cas où, à l'origine, le pilote a pu signaler lui-même quelque défaillance matérielle, vibrations, panne de l'horizon artificiel, mauvais

*Dans l'USAF en 1955, le taux des "causes indéterminées" a été de 14 pour cent d'apres MOSELEY

fonctionnement de l'inhalateur d'oxygène, etc. . . , bref, un début de situation critique en face de laquelle le pilote va réagir plus ou moins correctement, éviter l'accident ou y succomber. C'est ici qu'intervient l'équation personnelle de l'enquêteur Tel imputera l'accident au matériel, tel autre au personnel,* tel autre enfin hésitera à se prononcer et le classera "indéterminé".

ORGANISATION

Pour bien situer le problème dans son ambiance, il importe de rappeler brièvement quelle est, en France, *l'organisation de la sécurité des vols* dans l'Armée de l'Air.

A l'administration centrale†

(I)—Une section du 3 eme Bureau de l'Etat-Major de l'Armée de l'Air est chargée d'élaborer et de diffuser les règles concernant la sécurité des vols.

Sous l'autorité d'un Officier supérieur pilote, secondé d'un officier adjoint, cette Section comprend quatre sous-sections

—Une sous-section Chasse et Reconnaissance,
—Une sous-section Transport et Avions classiques,
—Une sous-section chargée de la rédaction du Bulletin de Sécurité des vols,
—Une sous-section médicale.

Par l'intermédiaire du Chef du 3 ème Bureau de l'EMAA la section "Sécurité des vols" dépend du Général Adjoint au Major Général de l'Armée de l'Air

La Section "Sécurité des vols" a connaissance de tous les accidents survenant dans l'Armée de l'Air, chaque accident faisant l'objet d'un rapport de modèle indentique où figurent les avis de l'Officier P N , de l'Officier mécanicien et du Médecin enquêteurs, ainsi que les avis des autorités hiérachiques.

D'autre part, la section est en liaison avec les Centres d'expériences aériennes militaires

(II) Une section de l'Inspection Générale de l'Armée de l'Air sous la direction d'un Officier supérieur du P.N. vérifie l'application des règles de la sécurité dans les Unités

Dans les Régions Aériennes et les Grands Commandements

Le 3 éme Bureau des Etats-Majors des Régions Aériennes et des Grands Commandements est chargé de diffuser aux unités les règles de sécurité des vols, de coordonner l'action des Officiers de sécurité des vols des unités, de faire la synthèse des comptes rendus de sécurité émanant des unités, éventuellement de prendre à son échelon les mesures destinées à améliorer la sécurité des unités volantes rattachées et d'en rendre compte à l'EMAA. Dans chaque Etat-Major Régional ou Grand Commandement, un Officier est désigné comme Officier enquêteur spécialisé. Il préside la Commission d'enquête constituée en cas d'accident

* Un pourcentage assez faible d'accidents est imputable non au Personnel Navigant, mais au personnel au sol (contrôle du trafic, maintenance, commandement)
† Ministère de la Défense Nationale, Secrétariat d'Etat aux Forces Armées "Air"

Dans les unités

Dans chaque unité aérienne et jusqu'à l'échelon Escadron, le Commandement désigne un Officier de sécurité des vols. Cet Officier est responsable de l'observation des règles de sécurité dans l'Unité. Il rédige les comptes rendus auxquels il lui est conseillé d'ajouter ses suggestions et critiques.

Rapport d'enquête

En cas d'accident, une Commission d'enquête est désignée par le Grand Commandement (Région, Air, DAT, GMMTA, CATAC, etc. . . .) dont dépend l'Unité aérienne à laquelle appartient l'appareil en cause.

Le Président de la Commission est l'Officier enquêteur spécialisé du Grand Commandement (Voir Paragraphe II). La Commission comprend un Officier pilote, un Officier mécanicien, un Médecin et éventuellement un Officier d'une autre spécialité du P.N. et un Officier des services administratifs

La Commission d'enquête établit un rapport d'enquête à l'aide d'imprimés réglementaires. Ces rapports parviennent au 3 ème Bureau de l'EMAA suivant deux voies, l'une hiérarchique, l'autre directe.

Le 3 ème Bureau de l'Etat-Major communique ces rapports à l'Inspection Générale de l'Armée de l'Air et, éventuellement, au Service du Matériel et au Centre d'Études et de Recherches de Médecine Aéronautique. Puis il clôture l'instruction et prend les décisions nécessaires.

Dans certains cas, des Commissions spéciales d'enquête peuvent être constituées par ordre du Secrétaire d'État—Commission d'enquête spéciale technique ou médicale, par exemple.

Projets

Il est envisagé de créer une École de Sécurité des Vols, qui, mieux qu'un bureau d'État-Major pourrait élaborer et expérimenter les règles concernant la sécurité. De plus, cette École instruirait des Officiers de sécurité spécialisés et des Officiers enquêteurs.

C'est le dépouillement de ces "dossiers d'enquête sur les accidents aériens", centralisés à la Section de la sécurité des vols à l'EMAA, qui nous a permis l'étude des cas concrets "d'accidents d'origine indéterminée" que nous voulons exposer maintenant

Notre travail porte sur les huit dernières années, de 1948 au premier semestre 1956 inclus.* Pendant cette période, 52 dossiers d'accidents aériens ont été classés comme dus à "une cause indéterminée". Cinquante ont été mortels Pour la présente étude, nous avons laissé de côté 13 accidents qui, à notre avis, n'entrent pas dans le cadre de la question posée. Il s'agit, en particulier, de multiplaces, dont: 2 disparus en mer (1 B-26 et 1 Wellington). 2 Beechcraft, 1 B161 Languedoc, 1 Martinet, 1 Anson et 6 avions légers Piper Cub, Morane 230, Ramier, pour lesquels, bien que la conclusion officielle de l'enquête soit négative, les circonstances de l'accident (conditions météorologiques, etc. . . .) se semblent pas présenter un intérêt du point de vue médical

Reste donc 39 accidents aériens qui font en réalité l'objet de notre étude.

* A l'exclusion des accidents survenus en opérations de guerre (IndoChine).

Types d'appareils

(I) *Avions école et avions d'entraînement des réserves*		
15, *dont*	P-47	3
	SIPA	4
	MS 472–475	2
	T-6	3
	T-33	3
(II) *Avions de chasse monoplaces à réaction* 22, *dont*		
	Vampire	1
	Mistral	2
	F-84-G	9
	Ouragan	8
	Mystere IV-A	2
(III) *Biplaces à réaction*		
	Meteor	1
(IV) *Hélicoptères*		
	Hiller 360	1

Age des pilotes

De 20 à 25 ans	27
De 26 à 30 ans	8
Plus de 30 ans	4

L'âge minimum est de 21 ans (5 pilotes)
L'âge maximum est de 47 ans (1 pilote)

Nombre d'heures de vol de chaque pilote

Moins de 100 h (c'est à dire élèves au dégrossissage ou aux premières phases de l'instruction)	néant
100 à 300 h (en majorité élèves en cours d'instruction)	8
De 301 à 1000 h (pilotes brevetés et confirmés)	22
Plus de 1000 h (pilotes anciens et très confirmés)	9

Le minimum d'heures de vol est de 120 Le maximum est de 1780 (1 moniteur qui s'est tué sur T-6)

Le pilote de l'hélicoptère, âgé de 30 ans, avait sur son carnet de vol 1950 h sur avions conventionnels, mais en réalité il n'était à l'entraînement sur hélicoptère que depuis très peu de temps C'était son premier vol solo après un vol avec moniteur.

Conditions de Vol

Altitude de l'avion au moment de l'accident ·

(I)	Au décollage ou dans les quelques minutes ayant suivi le décollage c'est à dire à moins de 500 m	10
(II)	De 500 à 3000 m, c'est à dire sans anoxémie plausible	9
(III)	Au-dessus de 3000 m (zone où le facteur anoxémie peut être discuté)	14

dont ·	à 4200 (m)	1
	à 4500 (m)	2
	à 6600 (m)	1
	à 7000 (m)	3
	à 7500 (m)	2
	à 7800 (m)	1
	à 9000 (m)	1
	à 10,500 (m)	1
	à 11,500 (m)	1
	à 13,500 (m)	1

(IV) Altitudes non précisées 6

Temps écoulé depuis le début du vol

Décollage (voir ci-dessus)	10
Moins de 30 min	11
Entre 31 et 60 min	9
Plus d'1 h	4
Non précisés	5
Maximum: 85 min	

Que conclure de ces données purement statistiques? peu de choses.

—Aucun des types d'avions en cause ne semble prédisposer plus particulièrement à l'accident inexpliqué. Si la majorité appartient aux F-84 et Ouragan, cela tient certes à leur performances élevées, mais surtout au fait que, lorsque la plupart des accidents sur ces types d'appareils se sont produits, ils constituaient un matériel révolutionnaire dont les performances et les modalités d'emploi n'étaient pas encore familières aux utilisateurs. C'est la chasse à réaction qui a le taux maximum d'accidents*, qu'ils soient expliqués ou non.

—Ce sont les pilotes âgés de moins de 25 ans, et ayant de 300 à 1000 h de vol qui fournissent le maximum d'accidents d'origine indéterminée. Mais cette ancienneté d'âge et de métier est celle de la majorité de nos pilotes d'Escadre qui, dans la statistique générale des accidents, figurent dans la même proportion.

On notera toutefois, parmi les accidents survenus en École, qu'un moni-

ı peu près autant
qu'aux altitudes
seulement que l'
hypothèse anoxie dont on sait l'importance, peut être envisagée, et nous y reviendrons

—Si nous avons précisé le temps écoulé entre le début du vol et l'accident c'est pour pouvoir discuter également l'hypothèse fatigue, sur laquelle nous reviendrons également.

En somme, cette étude statistique, encore que nécessaire, mais portant sur de petits nombres, ne permet pas de dégager une notion claire de la

ceux-ci
dents
›quée
dents
faut
admettre a priori qu'il y a deux ou trois chances sur une pour qu'il soit imputable au facteur humain.

Mais il ne s'agit pas ici d'exposer encore une fois toutes les causes possibles d'erreur humaine par défaillance physique ou par troubles psychologiques *ou anomalies de comportement*. Elles ont fait déjà l'objet d'études pertinentes et complètes, parmi lesquelles il faut connaître celle de PLACIDI et FLANDROIS, intitulée "Les malaises en vol"†, celle de H. G MOSELEY

* Exception faite pour les Centres d'entraînement des réserves

† *Méd aero 10, (3): 501, 1955.*

"Facteurs humains responsables d'accidents d'avion*", enfin les diverses communications sur la sécurité en vol présenté à la réunion de l'AGARD à Oslo et Copenhague en 1956.

Les unes et les autres ont parfaitement analysé les facteurs divers qui peuvent intervenir sur le plan général dans la genèse d'un accident (anoxie, dépression, température, etc. . . d'une part; psychoses, névroses, fautes par inattention, par indiscipline, etc. . . . d'autre part). Il serait oiseux d'y insister.

Nous nous contenterons, pour une étude de ce genre, de considérer chaque accident comme un cas d'espèce et, du point de vue médical qui nous occupe, de chercher le maximum de renseignements sur la personnalité physique et psychique du pilote et situer celui-ci dans l'ambiance de l'accident pour autant que les circonstances de cet accident aient pu être, sinon reconstituées du moins soupçonnées avec quelque chance d'exactitude.

Il y a évidemment des cas qui resteront toujours mystérieux. Ex. Deux sous-officiers de 25 et 26 ans, tous deux moniteurs ayant chacun 1600 h de vol, décollent sur T-6 pour une mission d'entraînement mutuel et de navigation Ils ont, l'un et l'autre, près de 300 h sur ce type d'appareil. Tous deux sont connus comme sérieux, consciencieux, et disciplinés. Le temps est beau. 15 min après le décollage, l'appareil s'écrase au sol, sur un itinéraire inverse de l'itinéraire prevu. Aucun message n'a été reçu de l'avion, concernant cette décision ou d'éventuelles difficultés. Qui pourra dire jamais ce qui s'est passé?

Autre exemple de même ordre Un sergent-Chef de 25 ans, 1000 h de vol, pilote confirmé et sérieux, décolle pour un vol d'entraînement en V S V. (Vol sans visibilité) sur Mistral. Arrivé à 2250 m environ, il s'engage en virage, puis en piqué et percute en mer. La mer gardera son secret.

Les exemples de ce genre sont nombreux

On est d'autant plus stupéfait que, le plus souvent, le drame se produit alors que le pilote avait jusque là communiqué avec le contrôle au sol ou avec son chef de patrouille, comme il est réglementaire, et que tout semblait se passer normalement

Exemples

—L (22 ans, 600 h) sur Mystère IV Après 23 min de vol à 13,500 m et 4 min après avoir signale sa position, s'écrase au sol. Résultats de l'enquête négatifs

—D. (22 ans, 300 h) sur F 84 G. Jeune pilote sortant de l'École de chasse et dont c'était la première mission à l'Escadrille Se montre nerveux au cours du vol en patrouille serrée à 6000 m. Après 1 h 15 de vol, le leader décide d'abréger l'exercice Alors qu'ils reviennent sur le terrain, à l'altitude de 1800 m et 5 sec après avoir correspondu correctement par radio avec son leader, il cesse de répondre aux questions de celui-ci, pique et percute au sol sous un angle assez faible. Le calme apparent de sa dernière communication radio est en contradiction avec sa façon de piloter brutale au manche.

L'enquête ne peut conclure qu'à une cause indéterminée.

L'incertitude est moindre dans certaines circonstances de vol.

En premier lieu, la traversée d'une couche nuageuse au cours de laquelle il y a eu vraisemblablement perte de contrôle.

* S.A E Reprint 743, Août 1956

—D. (28 ans, 780 h) sur F-84-G. Vol local en patrouille. Pénètre dans un nuage à 7000 m, en sort aux environs de la verticale, en plein orage. S'éjecte à basse altitude. Tué.

—D. M. (25 ans, 370 h) sur F-84-G. Vol en patrouille. A 10,500 m, après 18 min de vol, perd le contrôle de son appareil dans un nuage. S'éjecte, mais est retrouvé sanglé sur son siège, *parachute non ouvert, sans casque ni* inhalateur.

—Deux réservistes sur M-S 475 (l'un 34 ans, 205 h—l'autre 38 ans, 190 h). Exercice d'*interception. Après 18 min de vol comportant la tra*versée d'une couche nuageuse, l'avion abandonne la patrouille, déclenche dans un virage à gauche, pique et s'écrase au sol.

—V (25 ans, 470 h) *sur Mistral.* A 4200 *m*, après 1 *h* de vol, *signale dans* [illegible] plus. [illegible] h 13 de vol, sort des nuages à 600 m, pique et percute au sol.

—B (23 ans. 6 h) sur Mystère IV-A. A 1400 m le Chef de patrouille donne l'ordre à ses équipiers de se placer en formation étagée pour traverser [illegible] 2700 m [illegible]

La Commission d'enquête ne retient pas l'hypothèse "panne d'horizon mais pense à une fausse manoeuvre ayant entraîné "une perturbation des sensations d'équilibre et un affolement du pilote".

—B. (28 ans, 450 h) sur Meteor. 5 min après le décollage, après la traversée d'une couche nuageuse, en montée, perd à 2000 m le contact à vue avec son équipier. Continue en V.S.V. pique et percute.

La fréquence des accidents de cette catégorie a amené l'Armée de l'Air à organiser pour tous les pilotes de chasse des stages de V.S V. comportant en particulier des conférences faites par un médecin sur les aspects psycho-physiologiques du V.S V (équilibration, orientation, illusions sensorielles, vertige statique, etc. . .). L'ouverture de ces stages a été suivie d'une baisse sensible du taux des accidents aériens imputables au facteur humain.*

La perte de contrôle semble également plausible au cours de certaines manoeuvres telles que les suivantes.

—N. (22 ans, 570 h) sur Ouragan. Accoutumance au vol sans *bidons.* Après 15 min de vol, au cours d'un exercice de décrochage (prévu) pique et percute au sol

—G. (21 ans, 310 h), sur F-84-G. A 3600 m, après 40 min de vol en exercice de poursuite—début de vrille, part en piqué, largue son canopy, mais ne s'éjecte pas.

—V. (23 ans, 460 h) sur F-47. A 7000 m, après 1 h de vol, reçoit *l'ordre* de se rapprocher de son Chef de patrouille dont il s'est écarté, part en vrille, pique et s'écrase au sol.

—C de L. (21 ans, 345 h) sur Ouragan A 8000 m, après 42 *min de vol* en manoeuvre de combat, part en vrille à grand nombre de mach, ne s'éjecte pas, percute au sol.

* Cf SENEGAS et CANTONI "Aspect particulier du pilotage des avions à réaction au cours du V S V" *Méd aero* 11, (1) p 93, 1er trim 1956.

—P. (24 ans, 230 h) sur SIPA. Aussitôt après le décollage, l'équipier qui devait rassembler à l'extérieur par un virage à 180° à gauche se laisse déporter, pique et percute au sol sous un angle élevé.

Deux accidents d'origine indéterminée, d'où le pilote est sorti vivant sont à signaler particulièrement.

—H. capitaine, 35 ans, 3180 h de vol, dont 425 sur ce type d'appareil (MARTINET).

S'écrase au sol 2 min après le décollage. Le pilote rescapé, mais gravement blessé et choqué, ne se souvient de rien. La position de l'avion, qui n'a pas pris feu, permet d'affirmer qu'il n'y a pas eu perte de contrôle. B avait, comme co-pilote, un Adjudant-Chef également très ancien et confirmé, moniteur sur ce type d'appareil, qui fut tué dans cet accident.

—F. Adjudant-Chef, 25 ans, 1800 h de vol dont 100 h sur le type d' appareil en cause (F.84-G)

Très confirmé, a fait plus de 500 missions de guerre en Indochine.

Mission Essai d'un F-84-G après révision. Ressent un leger malaise avec respiration saccadée au cours de la montée, mais continue jusqu'à 11,500 m. Il voit toujours son tableau de bord mais n'y prête plus attention. Met son débit d'oxygène sur 100 pour cent au lieu de "Safety".

A la 20° min de vol, il perd le contrôle de son appareil et se met en compressibilité Il ne reprend pleinement conscience que lorsqu'un violent buffeting le tire de sa torpeur (vers 5000 m) Il redresse alors son appareil en effectuant des manoeuvres correctes et rentre au terrain malgré les difficultés du pilotage d'un avion déformé (il a pu noter 7·5 G à l'accéléromètre au moment de la ressource) Il se pose normalement après 1 h de vol.

Bien que les symptômes observés soient pleinement en faveur d'une anoxie aigue, probablement par mauvaise adaptation du masque au visage, l'enquête officielle conclut à une cause indéterminée.

En fait, cet accident pose le problème, signalé plus haut, de l'objectivité des conclusions des Commissions d'enquête normales Sans vouloir insinuer que, dans ce cas particulier, il y a eu faute quelconque dans la mise en place et l'utilisation du dispositif d'inhalation d'oxygène, il semble bien que la décision de clôture concernant cet accident aurait pu faire état d'un malaise anoxémique probable Il est bien d'autres cas ou pour des raisons humaines ou plus simplement administratives, les investigations des Commissions d'enquête ne sont pas poussées avec la vigueur nécessaire et pour peu que l'accident n'ait pas eu de trop graves conséquences, les choses en resteront là.

Tout cela prouve, une fois de plus combien il est important de connaitre l'histoire des incidents qui se terminent bien et des accidents "heureusement évités" Ceux-ci ne figurent pas toujours dans les statistiques Comme il n'y a pas eu perte de vies humaines, ni dommage au personnel ou matériel, le pilote, craignant qu'une faute ne lui soit imputée, ne croit pas devoir faire un rapport officiel. Le médecin est souvent mieux placé que quiconque pour en recevoir la confidence. PLACIDI et FLANDROIS, rapportant 64 observations de malaises en vol, estiment que "ce chiffre est inférieur à la réalité, car le médecin d'Escadre n'est pas toujours informé de la défaillance d'un pilote". Mais c'est à lui qu'il appartient de remédier à ce manque d'information en obtenant que ses camarades du Personnel Navigant viennent spontanément se confier à lui

Ceci revient à dire que les accidents *évités* sont plus instructifs que les accidents d'origine indéterminée. On s'en doutait.*

Ce qui ressort donc de notre étude rapide, c'est la *grande fréquence* des pertes de contrôle, en particulier dans les nuages et au cours de certaines évolutions de vol.

La question est alors de savoir si la perte de contrôle est due à un *malaise* physique, à une insuffisance d'instruction ou d'entrainement, ou à une *défaillance* psychique.

Le *malaise physique* dû aux effets de l'altitude, des *accélérations*, de la température, etc. ne peut, sur les 39 observations retenues, qu'être évoqué, (mais non affirmé).

L'hypothèse "anoxie d'altitude", aurait pu jouer dans les 14 accidents survenus entre 4500 et 13,500 m (et à condition qu'il y ait eu aux altitudes supérieures à 7000 m panne simultanée d'oxygène et de pressurisation) Cette proportion de 35 pour cent concorde avec celle des statistiques étrangères (32 pour cent d'après le "Flight Safety Research"). Nous n'avons toutefois trouvé trace, dans les dossiers d'accident, ni de rapports indiquant un mauvais fonctionnement antérieur du dispositif d'oxygène ou de la pressurisation cabine, ni d'indications (sauf peut-être dans eu cas) sur des changements dans la voix ou la parole du pilote au moment des dernières communications par radio, symptôme dont on connait la grande valeur.

Il nous a paru plus objectif de noter, dans ces cas, la durée du vol depuis le décollage:

à	6000 (m),	après	20	min	de vol	
à	7000	,,	,, 35	,,	,,	
à	7500	,,	,, 48	,,	,,	
à	7500	,,	,, 60	,,	,,	
à	7800	,,	,, 42	,,	,,	
à	9000	,,	,, 35	,,	,,	
à	11,500	,,	,, 20	,,		(cas non mortel)
à	13,500	,,	,, 23	,,	,,	

En l'absence de renseignements précis sur le temps passé réellement aux altitudes indiquées, il n'est pas question de parler ici de la "réserve de temps" chère aux physiologistes; mais on doit noter que dans tous ces cas, l'accident ne s'est pas produit dès l'arrivée à l'altitude en cause. Or, trois quarts d'heure ou une heure de vol sur chasseur à réaction font nécessairement penser à un degré de fatigue certain, surtout s'il existe un léger degré d'anoxie, et qui a pu être à l'origine de la perte de contrôle ou de la faute de pilotage ayant entrainé l'accident.

Les forces d'accélération, en tant que facteur prédominant éventuel n'apparaissent que dans trois ou quatre cas; mais par leur sommation, nous savons qu'elles sont également un facteur de fatigue.

Pourtant, la fatigue n'a pas joué dans les 21 accidents (sur 39) qui se sont produits au décollage ou dans les trente premières minutes du vol.

* Voir à ce sujet l'article de A. ACHIARY, V. ANDRE, CABANON et RICHET "Anoxies en vol" *Med. aero.* (Troisième trimestre 1956) et celui de T. J. POWEL (RCAF) "Episodic unconsciousness in pilots during Flight" *J Aviat Med.* 27, 4, 301, 1956.

Aussi faut-il attacher une grande importance aux fautes de pilotage en elles-mêmes, ou si l'on veut aux anomalies de comportement.

Avec MOSELEY, nous avons la conviction que les troubles psychiques vrais (psychoses, psychonévroses) sont dépistés dès l'admission dans le P.N. ou dès les premiers stades de l'instruction S'ils se manifestent plus tard, ils sont le plus souvent décelés à temps et ne constituent donc pas, en règle générale, une cause d'accident.

De même, le défaut d'adaptation, les préoccupations survenant chez des *sujets dont le comportement reste dans les limites normales, mais altèrent* leur jugement, et faisant d'eux des "énervés" sont remarqués en temps utile par les instructeurs ou les supérieurs et nous ont semblé n'avoir causé que relativement peu d'accidents.

Au contraire, les anomalies de comportement aboutissant à l'erreur-pilote, à la faute de pilotage (au sens général du mot) surtout sur les avions modernes

[illegible]

nous déclarer que "les jeunes pilotes qui lui arrivent de l'École ont encore tout à apprendre", ni un autre ajouter "mon Escadre n'est qu'un prolongement de l'École, le jeune pilote, qu'il soit élève-équipier ou, ensuite élève chef de patrouille, n'est encore qu'un élève, et mes cadres sont avant tout des moniteurs". C'est assez dire, que l'instruction reste le problème essentiel, non seulement en vue de l'efficacité opérationnelle mais aussi en vue de la sécurité des vols. Du point de vue psycho-physiologique, cela signifie la nécessité de l'acquisition des réflexes conditionnés et la mécanisation des réactions psycho-motrices, permettant à leur tour un meilleur équilibre et une plus grande stabilité du comportement.

La bibliographie aéro-médicale sur ce sujet commence à être abondante. Encore une fois, notre intention n'était pas de revenir sur ces données de plus en plus classiques

Nous nous contenterons, en terminant, de rappeler quelques principes généraux

(I) La défaillance humaine est chose normale, parce que les possibilités physiques et psychiques de l'homme sont limitées.

(II) Beaucoup d'accidents sont dus à ce que les caractéristiques de l'avion ont été fixées sans qu'il ait été suffisamment tenu compte de ces limitations

(III) La technique et la doctrine d'emploi de l'avion, élaborées et précisées au cours des essais en vol par un personnel hautement spécialisé, peuvent se révéler dangereuses lorsque l'avion de série passe aux mains d'un personnel moins qualifié

(IV) Le complexe "homme+machine" constitue un système fermé dont les parties réagissent l'une sur l'autre: si les performances de la machine augmentent, l'homme ne peut rester à la hauteur de sa tâche que grâce à l'aide d'un équipement dont la complexité et les défaillances constituent éventuellement pour lui un danger supplémentaire.

(V) Le *médecin qui s'occupe essentiellement* de l'"homme-individu" ne peut donc négliger "l'homme-instrument" comme dit GRAYBIEL, et le comportement de "l'homme dans le cockpit" doit être étudié par le médecin au même titre que son comportement dans la vie de tous les jours

Voilà qui est facile à dire, et peut-être moins facile à réaliser Dans le cockpit du Mystère IV il n'y a place que pour le pilote. Mais cette difficulté même met l'accent sur l'importance des "simulateurs de vol" (jet-trainers). Pour nous, médecins et psychologues, ils constituent un complément indispensable de la batterie de tests psychomoteurs—soit que le médecin assiste personnellement aux séances d'entrainement sur ces "trainers", soit que ceux-ci soient mis à sa disposition en vue d'un travail spécifique. Ainsi *pourra-t-il, chez un sujet donné, poursuivre l'étude synthétique* et concrète des aptitudes fondamentales mises préalablement en valeur par les méthodes analytiques de la psychotechnique, soit examiner plus en détail l'adaptation de ces aptitudes fondamentales à l'exécution d'une tâche particulière telle que la conduite d'un avion nouveau. L'idée n'est pas nouvelle. Le "Cambridge cockpit", les expériences de BARTLETT et la monographie de RUSSEL DAVIS sont bien connus* et peut-être auraient-ils pu être *exploités plus à* fond. Mais ce que nous préconisons spécialement, ce n'est plus l'emploi d'un cockpit standard, manié par des psychologues professionnels—c'est un "jet trainer" reproduisant exactement les caractéristiques de l'avion d'armes et sur lequel le médecin d'escadre observe le comportement des pilotes de son [illegible] avec [illegible]

teurs intelligents et connaissant à fond tous les aspects du facteur humain, de [illegible] *parfaitement* [illegible]

mettre en valeur certains facteurs subjectifs tels que la peur du vol, la phobie de l'altitude, et cette sorte de stupeur qui, parfois saisit l'homme com- [illegible] victime [illegible]

psychologique de prédisposition que le médecin est parfaitement qualifié à *explorer*

Sa participation à tous les stades de l'enquête sur les accidents aériens est une mesure excellente mais incomplète. Elle doit s'accompagner de la participation du médecin à tous les stades de l'instruction du pilote; son rôle dans la prévention des *accidents sera, nous en sommes* convaincus, plus direct, donc plus efficace

Nous n'en sommes pas encore là. Cette intrusion du médecin dans un domaine réservé est cependant de mieux en mieux comprise et admise par les Hautes Autorités responsables, aussi bien que dans *le cadre* de la vie

* Voir également les constatations faites en matière de sélection par P LABOUREUR et C JEST "Présentation d'un test synthétique pour la sélection des élèves-pilotes " Adaptation du "Visual Link Test" de la R C A F *Méd aéro* **11**, (1) · 101, 1956

quotidienne des escadres. Certes des résistances sont encore à vaincre. Elles seront vaincues Nécessité fait loi.

L'action de chacun de nous serait facilitée si de Groupe Aéro-Médical de l'AGARD voulait bien faire siennes les suggestions que nous venons d'exposer Nous envisageons donc de vous soumettre, soit à l'issue de ce symposium, soit au cours de la séance restreinte, un projet de "Recommandation" dans ce sens.

Summary

Participation by the flight surgeon in flight safety problems, particularly in the investigation of both explained and unexplained aircraft accidents, is indispensable. On the one hand, the human factor is involved in most cases; on the other, the flight surgeon can be on guard against abuse of the hypothesis of "human failure" which is advanced too often for insufficient cause.

Between 1947 and 1956, the number of aircraft accidents in the French Air Force has declined from 20 to 5 6 per 10,000 flying hours, and that of unexplained accidents from 0 8 to 0 48. However, these statistics must not be taken at face value. The definition of an "unexplained" accident or "unknown causes" is of necessity a negative one, and this somewhat elastic category permits different interpretations, frequently depending upon the personal approach of the investigator.

The organizational setup of "Flight Safety" in the French Air Force can be summarized as follows at the Chief of Air Staff level, there is a "Troisième Bureau" directorate, the Major Commands also have a "troisième bureau" division dealing with flight safety, and finally in the operational units, down to squadron level, there are the boards of inquiry which prepare reports of investigations

This paper deals with 39 accidents of unknown causes which occurred between 1948 and 1956. While the types of aircraft, pilots' ages, flying experience, flying conditions (including maximum altitude and duration of flight) are listed synoptically, this statistical compilation does not enable us to obtain a definite picture of the underlying cause of unexplained accidents

On the contrary, we find a great incidence of "loss of control" in flight by taking a detailed study of the circumstances surrounding each accident, the physical and psychological characteristics of the pilots involved, as well as by investigating non-fatal accidents and incidents This loss of control appears sometimes to be due physical indisposition, but much more often to anomalous behaviour aggravated lack of practical and theoretical experience This causes "Pilot Error" in the general meaning of the term

Without wanting to review the abundant data on the subject contained in the medical literature, the authors restate some general principles, among them necessity for the flight surgeon to study the behaviour of "the man in the cockpit" They make the following recommendations in this respect·

That the initial psychotechnical selection procedures (psychomotor test s) be augmented during instruction and training in the squadrons to psychophysiological observation of the pilot in the various flight simulators, by letting the flight surgeon be present during instruction runs on these training devices, or by making them available to him for special studies on the pilots;

(II) That special psychological indoctrination be given to flying instructors;

(III) That still more detailed psychophysiological indoctrination be given to flying personnel than is the case at present.

The authors propose to submit a formal recommendation to that effect to the AGARD Aeromedical Panel.

CONTRIBUTION A L'ÉTUDE DES ACCIDENTS D'ORIGINE INDÉTERMINÉE METTANT EN VALEUR L'IMPORTANCE DU COMPLEXE "PILOTE-AVION"

Médecin-Colonel SENEGAS et Médecine-Commandant CANTONI
France

POUR des facilités d'exposé, l'étude porte sur un groupement de Formations Aériennes caractérisées par l'utilisation d'une même catégorie d'avions monoplaces à réaction, ayant accompli un travail aérien bien défini, et soumis à la même doctrine d'emploi

La période considérée englobe les trois dernières années, au cours desquelles cet ensemble aérien a effectué 100,000 h de vol par an, soit au total 300,000 h de vol accomplies par un nombre moyen de 700 pilotes.

177 accidents ont été observés dont 10 ont eu pour origine une cause inconnue, soit 5 9 pour 10,000 h de vol et 0 30 pour ceux de cause indéterminée, ce qui apparait de prime abord négligeable

En réalité, l'étude des accidents dont la cause n'a pas été décelée prend une importance accrue si l'on envisage non plus l'ensemble des accidents, mais simplement ceux ayant entrainé, dans chaque cas, la mort du pilote.

En effet sur 46 pilotes tués par accident aérien, 10 ont trouvé la mort sans que l'enquête ait pu préciser les raisons réelles de l'accident En d'autres termes, dans plus de 20 pour cent des cas les enquêteurs ont été [illegible]

cadre de la Sécurité Aérienne

L'étude de cette catégorie d'accidents présente donc un intérêt majeur puisqu'elle s'étend sur près du quart des accidents mortels survenus en 3 ans dans la population considérée.

Dans la répartition des accidents, on constate que 4 sont survenus en 1954, 3 en 1955 et 3 en 1956. Il n'y a donc pas eu une régression sensible, alors que, pour la même période, le taux général des accidents aériens avait diminué de moitié De ce fait, si l'on étudie l'évolution des accidents d'origine indéterminée en fonction du nombre de pilotes tués par année, on s'aperçoit que

—pour l'année 1954: sur 25 accidents mortels,
4 ont eu une cause inconnue, soit 16 pour cent.

—pour l'année 1955: sur 13 accidents mortels,
3 ont eu une cause inconnue, soit 23 pour cent

—pour l'année 1956: sur 8 accidents mortels,
3 ont eu une cause inconnue, soit 38 pour cent.

(II) That special psychological indoctrination be given to flying instructors;

(III) That still more detailed psychophysiological indoctrination be given to flying personnel than is the case at present.

The authors propose to submit a formal recommendation to that effect to the AGARD Aeromedical Panel.

CONTRIBUTION A L'ÉTUDE DES ACCIDENTS D'ORIGINE INDÉTERMINÉE METTANT EN VALEUR L'IMPORTANCE DU COMPLEXE "PILOTE-AVION"

Médecin-Colonel SENEGAS et Médecine-Commandant CANTONI
France

POUR des facilités d'exposé, l'étude porte sur un groupement de Formations Aériennes caractérisées par l'utilisation d'une même catégorie d'avions monoplaces à réaction, ayant accompli un travail aérien bien défini, et soumis à la même doctrine d'emploi

La période considérée englobe les trois dernières années, au cours desquelles cet ensemble aérien a effectué 100,000 h de vol par an, soit au total 300,000 h de vol accomplies par un nombre moyen de 700 pilotes

177 accidents ont été observés dont 10 ont eu pour origine une cause inconnue, soit 5 9 pour 10,000 h de vol et 0·30 pour ceux de cause indéterminée, ce qui apparait de prime abord négligeable.

En réalité, l'étude des accidents dont la cause n'a pas été décelée prend une importance accrue si l'on envisage non plus l'ensemble des accidents, mais simplement ceux ayant entrainé, dans chaque cas, la mort du pilote.

En effet sur 46 pilotes tués par accident aérien, 10 ont trouvé la mort sans que l'enquête ait pu préciser les raisons réelles de l'accident. En d'autres termes, dans plus de 20 pour cent des cas les enquêteurs ont été contraints d'émettre des hypothèses, plus ou moins nombreuses suivant les circonstances de l'accident, et de trouver parmi elles celles qui paraissent les plus probables, afin d'en tirer des enseignements pour l'avenir, dans le cadre de la Sécurité Aérienne

L'étude de cette catégorie d'accidents présente donc un intérêt majeur puisqu'elle s'étend sur près du quart des accidents mortels survenus en 3 ans dans la population considérée.

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3 ont eu une cause inconnue, soit 38 pour cent.

En somme, chaque fois que les mesures de sécurité aérienne réduisent le nombre des accidents, en particulier ceux entrainant la mort du pilote, le pourcentage relatif des accidents d'origine indéterminée *ne cesse de* s'accroître, démontrant ainsi l'intérêt de leur analyse, en recueillant, en l'absence de renseignements décisifs qu'aurait pu donner le pilote, tous les élements capables d'orienter les enquêteurs vers des hypothèses reposant sur des données précises et permettant d'apporter des conclusions pratiques pour la prévention de tels accidents.

OBSERVATIONS RÉSUMÉES DES 10 ACCIDENTS
ANNÉE 1954

Cas n° 1

Sur avion MD 450 "OURAGAN", 15 min après le décollage, au début d'un "virage relatif" effectué à la vitesse de 300 noeuds et à 15,000 ft d'altitude, l'appareil déclenche en auto-rotation vers l'intérieur du virage, se stabilise, puis descend en vrille à plat, en sens inverse de la rotation [illegible] pilote.

Quoique l'accident soit imputable à une cause indéterminée, il semble bien cependant *que l'origine initiale de cet accident, soit* une action trop brutale du pilote peu expérimenté, qui a fait déclencher son appareil à partir d'une position en virage et fortement accélérée

On ne peut faire que des hypothèses sur les causes aggravantes qui *ont* fait que le pilote n'ait pu réussir à arrêter la vrille, larguer sa verrière en temps voulu, et s'éjecter.

Cas n° 2

Après un exercice de percée réelle en patrouille, sur F 84 G, le Chef de Patrouille fait mettre son équipier en formation de manoeuvre Des nuages fractionnés sous la couche de stratocumulus rendent la tenue de cette *formation difficile Par deux fois l'équipier perd* de vue son Chef de Patrouille au cours de traversées de bouchons nuageux et, ne parvenant pas à retrouver le contact, monte au-dessus de la couche. Le Chef de Patrouille ne répond plus à ses appels Son avion est retrouvé écrasé au flanc d'une colline qu'il a percutée en vol sur le dos.

Etant donné, que 1·5 min avant l'accident, le pilote a parlé avec son équipier et lui a donné des ordres de manoeuvres, l'hypothèse de la défaillance physique est peu probable. Le fait que l'avion ait percuté, sur le *dos, sous un angle de 40°, est une preuve pratiquement* certaine d'une perte de contrôle dans les nuages. En effet, si le pilote avait accroché à basse altitude, soit en vol horizontal, soit en virage, les débris de l'avion auraient été répandus sur une grande longueur

La perte de contrôle dans les nuages peut être imputée soit à la défaillance brutale de l'horizon gyroscopique, soit à une faute de pilotage en VSV. Le pilote était cependant très bien entraîné, parfaitement confirmé et venait de suivre un stage de VSV aux États-Unis.

Cas n° 3

Sur avion MD 450 "OURAGAN", au cours d'une percée réelle l'équipier quitte la patrouille à une altitude d'environ 3000 ft, sort des nuages à 2000 ft [illegible]

paraît vraisemblable, quoique la percée fut relativement facile à exécuter puisque pratiquement en ligne droite. Dans cette éventualité, on peut [illegible]

sur le dos, sous un angle de piqué accentué qui ne lui a pas permis de rétablir, ou de s'éjecter.

Cas n° 4

Au cours d'une mission d'entrainement, une patrouille de deux Ouragans équipés de tip-tanks part en retournement de combat, à l'altitude de 26,000 ft, pour attaquer une patrouille de F. 84 Dans cette manoeuvre, l'équipier décroche à grand nombre de Mach, et part en tonneaux déclenchés rapides, à gauche, aérofreins sortis Sa trajectoire s'incline rapidement jusqu'à 70° environ. Le pilote arrête une première fois la vrille après que son Chef de Patrouille lui ait indiqué de pousser fort sur le manche. Il repart aussitôt en sens inverse en vrille très rapide. Le pilote arrête une seconde fois l'auto-rotation pendant un temps assez long (1 à 2 sec). Le Chef de dispositif indique au pilote de tirer doucement sur le manche. L'avion se remet en vrille rapide, à gauche. Le Chef de dispositif donne au pilote l'ordre de s'éjecter. L'avion disparait vers 5000 ft dans les cumulus, percute le sol, explose et brûle.

L'enquête conclut qu'il s'agit vraisemblablement d'une panne dans le transfert des bidons, créant un déséquilibre par dissymétrie, non décelé par le pilote. Celui-ci, non averti s'est engagé en tonneau déclenché puis en vrille. Il n'a pas largué ses bidons, a tiré trop fort sur le manche pour sortir du piqué et s'est remis en vrille Enfin, il n'est pas arrivé à larguer sa verrière et n'a pu s'éjecter.

Année 1955

Cas n° 5

Le pilote décolle, sur "OURAGAN", pour effectuer un exercice comprenant d'après le cahier d'ordres percées QGH fictives, voltige à 12,000 ft, prise de terrain en configuration représentant les conditions d'un vol, moteur coupé

Une minute après que le pilote ait demandé l'autorisation d'effectuer sa voltige et annoncé qu'il restait en contact radio, l'avion s'écrase au sol. Le pilote qui s'est éjecté à très basse altitude est tué.

[illegible]

grandes marges de sécurité d'altitude (10,000 ft).

Cas n° 6

Sur avion "OURAGAN", au retour d'une mission d'assaut, l'avion qui vole à 500 ft, cabre doucement en virant, passe sur le dos, continue son évolution par un tonneau lent suivi d'un tonneau déclenché au cours duquel la verrière est larguée, et part en piqué à 45°, en vol sur le dos.

Peu après, un demi tonneau vraisemblablement contrôlé ramène l'avion en position normale. Le pilote amorce alors une ressource et s'éjecte à une altitude d'environ 130 ft, sans avoir rien annoncé à la radio. L'avion s'écrase, et prend feu.

L'hypothèse d'une inattention suivie d'une réaction brutale provoquant un tonneau déclenché est retenue par les enquêteurs, quoiqu'il s'agisse d'un pilote adroit et très expérimenté, nettement au-dessus de la moyenne. Il se peut qu'il y ait eu un déséquilibre dû au bidon droit incomplètement vide, ayant provoqué l'auto-rotation.

Cas n° 7

Sur F 84 G, au cours d'un exercice en patrouille simple, à 22,000 ft, l'avion disparait après 20 min de vol et percute le sol, sous un angle très fort. Le pilote n'a pas parlé à la radio, il n'a pas tenté de s'éjecter.

Les enquêteurs retiennent la possibilité d'une défaillance physique ou psychique chez un pilote revenant du Canada et peu entrainé sur F 84 G. La mise en compressibilité de son appareil peut avoir entrainé une perte de contrôle et une inhibition émotive enlevant tous les moyens de réagir utilement pour rétablir l'avion en vol normal.

Année 1956

Cas n° 8

[illegible] à 10,000 ft, le pilote au [illegible]

inconnue.

Cas n° 9

Sur avion "Mystère IV" au cours d'une mission à haute altitude (45,000 ft), 4 min environ après une transmission radio normale, le pilote perd le contrôle de l'appareil qui percute le sol à très grande vitesse sous un fort angle de piqué. Avant de s'écraser le pilote largue la verrière mais n'a pas le temps de s'éjecter.

L'hypothèse d'une perte de connaissance par arrêt de l'alimentation en oxygène parait la plus probable, pour deux raisons:

(I) le pilote semble avoir repris ses sens à basse altitude mais trop tard;
(II) les signes d'anoxémie se sont manifestés 3 min après l'heure estimée à laquelle il devait atteindre l'altitude de 45,000 ft

Cas n° 10

Sur avion "Mystère IV", en exercice de navigation de nuit, à 20,000 ft, 17 min après le décollage, l'appareil percute le sol, sous un angle voisin de la verticale et en dehors de la route prévue.

Le pilote, après avoir signalé sa position par radio dans la prem
partie de la mission, ne fait plus aucun appel.

Les hypothèses émises par les enquêteurs peuvent être classées par ordr
probabilité décroissante:

(I) Erreur de navigation suivie d'une perte de contrôle dans les nua
due peut-être à une panne d'instruments,

(II) Malaise en vol,

(III) Panne électrique totale et emballement du Flettner.

DISCUSSION

Des 10 observations ci-dessus présentées, il ressort que tous les accid
sont caractérisés par une perte de contrôle de l'appareil au cours de laq
le pilote ne s'est pas éjecté ou a tenté l'éjection trop tardivement.

—80 pour cent des accidents sont survenus sur avions "OURAGAN
"MYSTERE IV" et 20 pour cent seulement sur F 84 G ou F, alors
ceux-ci constituent les 2/3 de la Flotte aérienne considérés.

—90 pour cent des accidents ont eu lieu à des altitudes telles qu
possibilité d'une défaillance physique ou psycho-physiologique par hyp
reste peu probable, même en envisageant une pressurisation défectu
de la cabine. Seule, dans le cas No. 9 la perte de connaissance du p
apparait probable et semble liée à un état anoxémique brutal et accé
par la période digestive

La fréquence des accidents survenus sur certains types d'appareils
en relief l'importance du complexe pilote-avion, dans l'origine de ces
dents de cause indéterminée. Pour un même travail aérien, le risque
suivant des facteurs multiples dont la connaissance de certains ne peut

[illegible]

cessent de s'accroître, alors que les moyens qui sont mis à la disposition
pilote pour contrôler sa position dans l'espace, deviennent relativemen
plus en plus insuffisants.

En particulier, parmi les instruments de bord, l'horizon artificiel g
scopique est trop sensible aux accélérations et par son inertie ne permet
des lectures exactes rapides. Le variomètre est par contre trop lent e
donne des lectures exactes qu' avec un très grand retard. Si le pilote
pas familiarisé à piloter au "panneau réduit", c'est-à-dire uniquement

[illegible]

doivent tendre tous les efforts des techniciens, ingénieurs, médecins et psychologues, travaillant en commun. Certes si l'entrainement rationnel, contrôlé et progressif doit jouer un rôle prépondérant pour développer les aptitudes requises et permettre une connaissance approfondie du matériel, il n'en reste pas moins que toute amélioration des moyens mis à la disposition du pilote pour connaître immédiatement, et à tout instant, sa position dans l'espace, réduira considérablement le nombre des accidents dont l'origine était restée jusqu'alors, difficile à déterminer.

Summary

In the first section of this paper, the authors give detailed observations of 10 *aircraft accidents for which no cause could be found. These accidents happened in the First Tactical Air Corps during the last* 3 *years and involved single-seater jet aircraft.*

The second section gives a synthesis of these accidents which emphasizes the importance of the pilot-aircraft complex confronted with aerial hazards, classified according to different types of aircraft.

In conclusion, the authors state that the adaptation of man to the aircraft will remain a perennial problem due to the rapid evolution of modern aviation.

FACTORS RELATED TO UNEXPLAINED ACCIDENTS IN THE U.S. AIR FORCES IN EUROPE

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I should like to present some data and opinions about aircraft accidents in the United States Air Forces in Europe. Since the subject concerns accidents for which no absolutely conclusive explanation was found, and because specific causes are often difficult or impossible to establish, some latitude is required for speculation on aeromedical factors and the probability that they were, indeed, involved. This paper is not an attempt at a comprehensive study of medical factors in aviation accidents, nor does it prove anything statistically. The numbers that I shall mention later are useful mainly to emphasize the continuing importance of factors that are already well known in aviation medicine.

When the accident investigation shows that such non-medical events as material failure, known pilot error, or severe weather were very improbable, one's suspicion of hypoxia, vertigo, blackout, and other aeromedical hazards of flight tends to rise. Caution is necessary, however, because even when non-medical cause factors can be proved it is not always possible to eliminate the medical factors as secondary or, indeed, as the primary cause of the accident. Hence, in the unexplained accident, the investigator is nearly always confronted with the question of the pilot's physical and psychological fitness and whether or not he was incapacitated during flight. The importance of catastrophic medical events such as acute coronary thrombosis or an epileptic seizure is acknowledged, as are the less dramatic but equally treacherous diseases that can produce aviation tragedies; however, the incidence of such events in our active pilot group seems to be very low; at least we lack proof to the contrary. Much more important, in my opinion, are the time honoured and ever present aeromedical complications of flight that render incompetent or incapacitated the otherwise healthy pilot—acute hypoxia and spatial disorientation, to name just two which demand our enduring respect Many here will recall that last year Dr Powell of the Royal Canadian Air Force reported[1] 9 cases of unconsciousness in RCAF [illegible]

lasted for 10 sec in one to 6 min in the extreme case. What were the causes? One severe hypoxia; two epilepsies; one alcoholic hangover without adequate food before flight; one severe vertigo with nausea and clouding of consciousness; a fear of formation flying without true unconsciousness; and one case unexplained. The hypoxia case was an experienced pilot with 2800 hr, of which 600 hr were in jets.

Last October, I had an opportunity to interview four Norwegian fighter pilots who had had episodes of unconsciousness during flights in F-84 F's.

These cases were very thoroughly investigated by the Royal Norwegian Air Force. Unconsciousness ranged from a few seconds to more than one minute One was a highly experienced officer with more than 1000 hr of jet time; the cause of his incident was most probably a loose fitting oxygen mask which has aged beyond serviceability. In one case there was a combination of no food on the day of flight, repeated G stresses during flight and fatigue from severe physical exertion on the previous day; however, the relative importance of these factors could not be proved. The other two incidents seemed to be hypoxia probably caused by poorly fitting oxygen masks.

A review[2] of U.S. *Air Force major jet aircraft accidents during the period* 1 July 1954 through 31 December 1955 indicates that, excluding take-off mishaps and mid-air collisions, there were 194 major accidents in the cause undetermined category, with 206 fatalities. Of these, the circumstances of the accidents were such that 32 per cent could have been caused by hypoxia

The present study is based upon a questionnaire survey of US Air Force flyers who had physiological training at the 7112th Central Medical Group between September 1955 and July 1956. The questionnaire covered six areas of interest: hypoxia, spatial disorientation (pilot's vertigo) hyperventilation, rapid or explosive decompression, decompression sickness, and the important related matter, personal protective equipment.

Table I shows the gross results of the survey.

Table I—Aeromedical Incident and Equipment Survey among USAFE Flyers: Sept. 1955–June 1956

questionnaires submitted		865
no response	35	
neg response	106	
positive responses	724	
pos responses, pers equip. only	104	
pos responses, pers equip and aeromed incidents	346	450
pos responses, aeromed incidents only	274	620

Some 865 questionnaires were submitted. Of these, 35 contained no entries at all and, in 106, all questions were answered negatively. There were 724 in which one or more of the 6 categories of questions had positive comments; of these, 104 reported on personal equipment only; 346 offered comments on personal equipment as well as aero-medical incidents; and 274 restricted their entries to aeromedical incidents. As a result, we obtained 450 reports on personal equipment, and 620 on aeromedical incidents. It should be added that, although the great majority of the reports concerned episodes that occurred during the flyer's current assignment in the USAFE, some few had taken place in other commands prior to the European assignment.

Table II shows the reported occurrence of in-flight incidents that were of special aeromedical concern.

Table II—Reported Aeromedical Incidents (based upon 620 "positive" questionnaires)

hypoxia	188	30 3 (per cent)
hyperventilation	27	4 4 ,, ,,
sudden decompression	107	17 2 ,, ,,
decompression sickness	73	11 8 ,, ,,
*Pilot's vertigo (spatial disorientation)	685	100 0 ,, ,,

*Figures obtained from previous study by NUTTALL and SANFORD

Based upon the 620 so-called "positive" questionnaires, there were 188 flyers (30·3 per cent) who had had one or more hypoxia incidents; 27 (4·4 per cent) with histories of hyperventilation; 107 (17·2 per cent) who had experienced rapid or explosive decompressions; and 73 (11 8 per cent) who had had decompression sickness. I have listed spatial disorientation (pilot's vertigo) last in the table because the figures were obtained from a previous study[3] by NUTTALL and SANFORD in which it was concluded that, at one time or another, all pilots experience the illusions of flight that lead so readily to spatial disorientation.

In *Table III* we see that, of the 188 individuals who reported one or more episodes of hypoxia, 161 or 85 per cent were moderately severe, 15 or 8 per cent were severe, and 12 or 6·4 per cent were so severe that incapacitation and unconsciousness resulted.

Table III—Reported Hypoxia Incidents
(based upon 620 "positive" questionnaires)

Flyers reporting episodes of hypoxia	188	30 3 (per cent)
Severity.		
Mild	not applicable	
Moderate	161	85 6 ,, ,,
Severe	15	8 0 ,, ,,
Severe, incapacitated	12	6·4 ,, ,,

Hypoxia was not a most probable cause in any of USAFE'S twenty-three major accidents, 1955 and 1956, it was ruled out as a possible contributing factor in all but one case.

A typical example· a pilot flying at 35,000 ft noticed blurred vision, started an immediate descent, and lost consciousness at 30,000 ft; he came to at 9000 ft. He stated that he lost control of the aircraft and that he was

avoiding the "mild hypoxia" classification. This is based on the view that if the hypoxia has progressed to the point of recognition by the victim, it has already passed the mild stage. In the U.S. Air Forces in Europe during 1955 and 1956, there were twenty-three major aircraft accidents in the cause undetermined category.* Hypoxia was not indicated as the most

U.S. Air Force are by no means rare. As a result, one tends towards the impression that even though hypoxia occurs with uncomfortable frequency, the experienced flyers are sufficiently well trained and alert to cope with it in the majority of cases. This is perhaps a dangerous impression, certainly it should not suggest that we relax our efforts to reduce hypoxia incidents to nil.

* It should be noted that, before accepting any factor as the primary cause of an accident, the U S Air Force requires proof beyond reasonable doubt; hence, many accidents which almost certainly resulted from material failure remain, for lack of specific proof, in the cause undetermined category.

In their excellent paper on spatial disorientation[3], NUTTALL and SANFORD concluded that "pilot's vertigo" of some degree is universally experienced by flyers. In their study, as indicated in *Table IV*, 685 pilots were interviewed, 478 of whom were jet pilots.

*Table IV.—Reported "Pilot's Vertigo" (Spatial Disorientation)**
(based upon interviews of 478 jet pilots and 207 non-jet pilots)

Pilots reporting "vertigo" experience	685	100 (per cent)
Severity:		
Mild	508	74 1 (per cent)
Moderate	145	21 2 ,, ,,
Severe	32	4 7 ,, ,,

"Vertigo" was the most probable cause of 4 (17 per cent) and could not be ruled out as possibly contributing in another 5 (22 per cent) of the 1955 and 1956 USAFE major, cause underdetermined accidents.

* Data from 1956 AGARD Aeromedical Panel paper by NUTTALL and SANFORD.

Some 508 had one or more episodes of mild "vertigo"; 145 had one or more instances of moderately severe "vertigo" defined as having some adverse effects on flying proficiency and producing moderate mental stress; and 32 gave a history of severe "vertigo" defined as producing severe mental stress and usually resulting in complete loss of control of the aircraft. It was concluded that while "pilot's vertigo" is a significant flight safety problem, the great majority of pilots either do not consider it an important problem or feel that it is a circumstance of flight which can be adequately dealt with through proper training and practice. However, the following observation suggests that our pilots are not sufficiently impressed with the importance of "vertigo" as an accident factor. of the 23 major unexplained accidents in the USAFE in 1955 and 1956, 4 were thought to be most probably caused by "vertigo", and in 5 others, "vertigo" could not be ruled out as a possible contributing factor.

Hyperventilation, decompression sickness, and explosive and rapid decompression episodes have, for convenience, been grouped together in *Table V*. Our reported experience suggests that, although these events are

Table V—Reported Hyperventilation, Sudden Decompression, and Decompression Sickness Incidents
(based upon 620 "positive" questionnaires)

			Mild	Mod	Severe
Hyperventilation	27	4 4 (per cent)	21	5	1
Decompression sickness	73	11 8 ,, ,,	57	15	1
Sudden decompression	*107*	*17 2 ,, ,,*	68*	35	4

Hyperventilation, decompression sickness, and sudden decompression were not implicated as probable factors in USAFE 1955 and 1956 unexplained accidents

*See explanation, page 159 of text.

hazards to flight safety and crew effectiveness, they are not as common in their severe consequences as are hypoxia and spatial disorientation. It seems reasonable that hyperventilation is probably a more important problem in [illegible] be borne out

Finally, because a well planned and operated personal protective equipment programme is considered absolutely fundamental to crew effective- [illegible] have been made. *Table VI* indicates that of the 450 flyers who submitted positive comments, 72 or 16 per cent were favourable. In contrast, 378 or 84 per cent of this group registered complaints, the majority of which were serious. In the unfavourable group, 82 per cent of the complaints were reported by jet pilots. Complaints were aimed at maintenance and supply, related logistical difficulties of personal equipment and lack of trained personnel. The majority seemed to regard the design of equipment as satisfactory or better since only 5 per cent considered equipment design as faulty. During the past year progress has been made in improving the personal equipment supply.

Table VI—Views of USAFE Flyers on Personal Equipment
(based upon 450 "positive" questionnaires)

Comments:				
Favourable	72	16·0 per cent		
Unfavourable	378	84·0 per cent		
Sources:	*Jet pilots*	*Non-jet pilots*	*Officer crew*	*Enlisted crew*
Favourable	33*	20	13	6
Unfavourable	311	38	20	9

In 344 of the 378 unfavourable comments, *inadequate supply* was reported as the important factor.

* Includes 10 RCAF (in all cases, RCAF pilots reported their personal equipment as good to excellent).

In summary, the following points deserve emphasis. The reported experiences of USAFE flyers impressively show that hypoxia and spatial disorientation, and to a lesser extent, decompression sickness and hyperventilation are important and continuing threats to flight safety and crew effectiveness. We recognize a serious and compelling requirement to improve the logistics and maintenance of personal protective flying equipment. The reported USAFE experiences firmly support the present USAFE policy that requires thorough refresher training of jet aircrew personnel in flight physiology and protective equipment every 18 months. In the USAFE experience may be found ample justification for both fundamental and applied research aimed at a better understanding of human performance capabilities and limitations and at improving the design and reliability of the equipment that is essential to flying safety and aircrew effectiveness.

Sommaire

Une étude portant sur l'interrogatoire de 862 aviateurs de l'U.S. Air Force en Europe a permis d'avoir des renseignements sur la fréquence des incidents d'intérêt aéro-médical survenus en vol et comprenant l'hypoxie, l'hyperventilation, la décompression rapide ou explosive, le mal de décompression et le vertige du pilote.

Hypoxie et vertige constituent toujours les facteurs primordiaux d'ordre aéro-médical dans les accidents d'aviation majeurs. En outre, on a demandé au Personnel Navigant de l'USAF en Europe ce qu'il pensait de la qualité et de la fourniture de l'équipement individuel de protection en vol, sur les bases aériennes. L'approvisionnement insuffisant en matériel indispensable de cet ordre reste un problème non résolu.

Les accidents aériens majeurs de 1955 *et* 1956 *dans la catégorie "cause indéterminée" ont été étudiés en vue d'évaluer dans quelle proportion les facteurs aéro-médicaux ont été ou auraient pu être des causes premières ou secondes d'accidents.*

Les données sont présentées sous forme graphique, avec la relation des cas démonstratifs.

References

[1] Powell, T. "Episodic Unconsciousness in Pilots During Flight". *J. Aviat Med.* Vol 27, No. 4, pp. 301-316.

[2] Konecci E B. "Hypoxia and Undetermined Jet Accidents", Publications 43-56, Dir Flight Safety Research, USAF, Norton Air Force Base, California.

[3] Nuttall, J. B and Sanford, W. G. "Spatial Disorientation in Operational Flying", Publication M-27-56, Dir Flight Safety Research, USAF, Norton Air Force Base, California

III. USE OF PATHOLOGY IN CRASH INJURIES

THE UTILIZATION OF PATHOLOGY IN AIRCRAFT ACCIDENT INVESTIGATION

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AIRCRAFT accidents continue to be a problem within the United States Air Force. Concern regarding these accidents arises initially because of the humanitarian aspects involved, a feature which defies ultimate evaluation. The Air Force is also confronted with the practical military viewpoint of conserving its combat capability, both pilots and planes. The economic loss of a modern airplane is enormous, and the loss of a single pilot requires a great investment to achieve a replacement of equal training and ability.

In order to place the matter in its proper perspective, it is necessary to cite previous experience of the United States Air Force regarding aircraft accidents.[1] In 1922, there were 506 major aircraft accidents per 100,000 flying hours which in 1955 had been reduced to 17 major accidents per 100,000 flying hours. In spite of this remarkable record there has been an increased incidence of fatal accidents, in 1930 there was an average of one fatal accident in every 13 major accidents, while currently one out of every 5 major accidents results in a fatality. During the past five years over 4800 people have been killed in United States Air Force aircraft accidents and [illegible] responsible for 40 per cent of the fatal accidents.

Naturally, any solution to this problem rests with the flight safety personnel and must of necessity centre about two major features; first, to find the cause of an accident and secondly, to propound its prevention. Aeronautical engineers have kept pace in their investigations concerning accident causation and prevention which is well exemplified by their past record.[3] It now [illegible] required for such an endeavour, the field of pathology is primarily concerned with the structural and functional changes in disease and consequently, it is believed, offers considerable prospect in the co-ordination of flight safety information. The well-established sub-speciality of Forensic Pathology has demonstrated this scientific discipline's usefulness in establishing cause of death, sequence of events, etc.

The pathologist's contribution can prove invaluable, particularly if he has a prior understanding of the magnitude of the problems involved. An investigation by a pathologist should encompass all the many factors which

affect the 'man-aircraft" relationship and for the purposes of simplifi the approach to this field has been threefold; including a considera (I) the environmental factors, (II) traumatic factors, and (III) pre-e disease.[3] *Table I* presents these features in greater detail.

Table I

(I)

(II) Traumatic factors
- (a) Protective equipment
- (b) Escape
- (c) Aircraft design

(III) Pre-existing disease

The environmental factors are deserving of continuing intensive re and investigation in order to ferret out the enigmas which must be l there. There is need to accumulate data regarding the recurring pl traumas produced in accidents so that injury might be prevented by n cation of experimental aircraft. Every effort must be exerted to de means to predetermine those pre-existing diseases which may incapa a crew member.

The following examples and their associated discussions may ser focus attention to some of the above mentioned facets:

Case 1. *Hypoxia*

Twenty minutes after take-off, a jet trainer levelled off at 35,000 ft a cabin pressure of 29,000 ft. Oxygen check at this times was stated as " by the passenger who was also a rated pilot. Five minutes later the heard the passenger taking off his mask. The passenger made the remark it was too tight and he loosened it. The pilot then asked the passeng tune in the radio station, and when the passenger said that he could not the radio station, the pilot asked him to fly the aircraft while he four The passenger competently flew and after 4 min relinquished the cor satisfactorily. Six minutes later, the pilot called for another oxygen c and received no reply from the passenger. The pilot then asked the c aircraft in the flight visually to check the occupant in the rear cockpit. pilot of the second aircraft noted the passenger was slumped over. mediate descent at the Mach limit was instituted and within a few mir they were on the ground with medical personnel waiting. Attempt resuscitation were unsuccessful. A subsequent equipment check showed mask to be deficient although the oxygen system was in order. In itself case does not represent an aircraft accident but the consequences i single-place aircraft are obvious.

Discussion—Unfortunately there are no unequivocal histopathol changes in death from acute hypoxia or anoxia as contrasted with the n evident abnormalities associated with chronic hypoxia. Nonetheless, i

co-operative venture by the Royal Canadian Air Force Institute of Aviation Medicine and the School of Aviation Medicine, USAF, there has been devised a test on post-mortem tissues that would give some clue as to the existence of ante-mortem hypoxia.[4] This test for lactic acid in brain or spinal cord has shown promise especially in laboratory animals although the ultimate value of the procedure will have to await further correlative study.

The School of Aviation Medicine, USAF, has developed a technique whereby carbon monoxide may be determined from post-mortem tissue.[5] Data from the Directorate of Flight Safety Research, Office of the Inspector General, USAF, indicate that in most instances of an elevated tissue carbon monoxide volume there has been an explosion on impact or an in-flight fire. In order to continue to evaluate the method and the possible role of carbon monoxide in aircraft accidents, determinations are made routinely whenever unfixed tissue is made available by the autopsy surgeon.[6]

Case 2. Decompression sickness

This case cited from HAYMAKER *et al*[7] involved a two-seated jet traine Ninety minutes after take-off while at an altitude of 39,000 ft with a cab pressurization of 29,000 ft, the passenger, a 34 year old, obese, white ma complained of numbness of his left side and became incoherent. A raj descent was started and minutes later the plane was on the ground. T patient was semi-comatose and there was a pronounced left-sided paral In spite of supportive therapy instituted at the hospital, the patient tinued a down hill course and expired 6 hr after the onset of his illness.

Discussion—The post-mortem findings in this case were thought to be to a combination fat and aero-embolism Intense intravascular fat was f within the lungs and via a patent foramen ovale also within the brain. areas of cerebral ischemic necrosis were noted to be indistinguishable those due to aero-embolism. The pathogenesis of this condition post was as follows: adipose tissue contains a supersaturation of ga bubble formation occurring upon decompression which is follov rupture of the cells and release of their fat and gas into the vascular

The simple explanation of embolism may actually reflect a mor mental change brought about by this condition and is an area i considerable more investigation is needed. A study of the pat findings in cases of death due to in-flight decompression sicknes by the Royal Air Force Institute of Aviation Medicine and the Arm Institute of Pathology has brought this problem into sharper dictates the need for further experimental studies of this phenomen

Case 3. Spatial disorientation

The pilot was on a night radar training mission at an assigne 23,000 ft. Throughout the flight, all communications were clear and upon satisfactory completion of the radar portion of the fli returned to the base to practice touch and go landings. T instructed to change his radio to tower frequency and he re radio channel 2 was being selected. There were no further r ...and 3 min later a ground explosion was sighted. Investi... ...disintegrated upon contact and that the pi...

injured. No attempt has been made to eject. The cause of the accident was undetermined; however, the suspected cause is spatial disorientation and the pilot in resultant confusion flew the aircraft into the ground at a high rate of descent.[10]

Discussion—The above example is only one of many such instances in which the last communication from the pilot concerned this changing radio

by instruments following such activities as changing the radio channel. If an unnatural attitude is assumed during such a manoeuvre, it is quite possible for a pilot to fly into the ground before corrective action can be taken. A sharp decline in the frequency of this type accident has followed the movement of the radio selector panel into the pilot's line of sight. Yet, as far as can be determined, in no such instance as in the case cited, has the inner ear been removed at post-mortem examination for pathologic examination. These errors of omission will do little to help clarify this perplexing problem.

Case 4. Traumatic factors

malfunction.

en fire in the

ilot, co-pilot,

navigator and instructor navigator. Reconstruction of the sequence of events from all available information shows the following: the navigator, seated in the nose of the plane, ejected, but at too low an altitude for survival The instructor navigator apparently attempted to exit through the main entrance door, his only means of escape. There must have been a sudden

of the

happened to the remains of the instructor navigator. The co-pilot's body was described as fragmented. The pilot was thrown clear of the wreckage. Although his body was intact he sustained burns of the face and arms

Discussion—Post-mortem material was received on all crew members except the instructor navigator From the information available no tissue was found on the latter individual. The only unfixed material for toxicology received was from the navigator and consisted of brain tissue. The lactic acid level was elevated and this was interpreted to be probably an indication of hyper-ventilation during the terminal stages of the flight since the aircraft was at too low an altitude (200 ft) for hypoxia to play a role. Tissue carbon monoxide was negative. In addition to fixed tissue for histopathology studies on the navigator, random tissue for histopathology studies were received on the pilot and co-pilot. In the case of the pilot, spinal cord was received in the fixed state, but no samples of the burned skin. It would have been interesting to study sections from the burned areas to determine, if possible whether the burns were incurred *ante mortem* while in the aircraft, or *post mortem* from radiant energy effect of the fire at the site of the crash If the

spinal cord had been submitted in an unfixed state for toxicology studies it would have been more useful in that a determination of carbon monoxide would have also been a clue as to how much fire and smoke the pilot was

fixed state for histologic examination. Elevated carbon monoxide levels would have helped substantiate the theory that there was fire in the cockpit prior to impact. This case serves to illustrate that the individual performing the autopsy should be acquainted with all of the known circumstances surrounding an accident and direct his investigation efforts along the lines that will best answer the questions raised in each particular case. The effort expended in obtaining spinal cord tissue from the pilot in this accident was

furnished much useful information regarding the nature of the burns and the time of their occurrence

There is urgent need for a careful evaluation of sequence of traumatic events incurred in aircraft accidents so that we may better cope with the problems of aircraft design, escape mechanisms, etc. A recent study[11] of 289 gross autopsy protocols demonstrated that frequently only lethal head injuries were encountered in aircraft accidents occurring during the landing and take-off phase. When it is realized that nearly two-thirds of our accidents occur at these critical stages of flight, this observation seems to dictate the need for better head protection during this phase of flight. In several instances death has been due to remediable hemorrhage which points up the desire for a more rapid medical rescue. The need for critical study of bail-out cases has been emphasized,[12] for in several cases a careful examination by a pathologist has led to a clarification of the sequence of events that occurred in fatal cases of ejection bail-out. Data of this type can be of great use to our equipment designers for further reference. A more careful evaluation of burns sustained by crew members may be of value in aiding the material investigators to answer problems concerning the origin of the fire, its duration and intensity.[13]

Case 5. Pre-existing disease

During the let-down procedure, a 34 year old co-pilot of a C-46 aircraft suddenly stiffened in his seat, became unconscious, and upon landing was pronounced dead. He had expressed no complaints and his behaviour had been normal until the sudden onset of his illness. An autopsy revealed severe coronary atherosclerosis as the only cause of his sudden demise.

Discussion—It is easy to visualize the outcome of such an incident had this man been the pilot of a single-place aircraft and the result may well have been another unexplained aircraft accident. Other examples of pre-existing disease on file at the Armed Forces Institute of Pathology which have produced sudden incapacitation or death in pilots include brain tumours, sickle cell anemia, laryngocele and abdominal adhesions. It is obvious that

trois chapitres d'intérêt majeur: facteurs d'ambiance, facteurs traumatiques et défectuosités pré-existantes.

L'étude des facteurs d'ambiance comprend les dangers résultant de l'altitude, les effets possibles de la vitesse et des forces d'accélération, les toxiques tels que CO, *carburants, liquides hydrauliques; les températures extrêmes, les bruits et vibrations excessifs, et le rôle du stress. Les facteurs traumatiques doivent être examinés soigneusement quant à leur rôle dans la valeur de l'équipement protecteur, l'évacuation du bord et les caractéristiques de l'avion. Comme exemples d'affection pré-existante qui peut frapper d'incapacité un pilote au cours du vol, on peut citer l'athéro-sclérose coronarienne, des kystes du troisième ventricule, l'anémie à hématies falciformes, et l'emphysème.*

La discussion de ces aspects est présentée avec des cas démonstratifs pour illustrer la contribution que l'anatomie pathologique peut apporter aux enquêtes sur les accidents d'avion.

L'U S. Air Force a rédigé une directive concernant l'enquête médicale sur les cas mortels par accident d'avion, qui esquisse la marche à suivre systématique pour les recherches post-mortem, avec recours à la toxicologie, la radiologie et la photographie.

References

1 Caldera, J. D. Flight Safety Testimony, Special Report No. 31-56 Given [illegible] of Representatives, a [illegible] Research, Office of the [illegible]

2 Air Force Manual 62-5. Aircraft Accident Prevention—Investigation—Reporting. Dept of the Air Force, 1 February 1956.

3 Townsend, F. M., Stembridge, V. A. and Mostofi, F. K. "The Role of the Pathologist in Aircraft Accident Investigations". *Aeronaut. Engng Rev* (in Press).

4 Franks, W. R. "Further Experience with Detection of Anoxia in Fatal Accidents". Paper read before 25th Annual Meeting Aero Medical Assoc., Washington, D.C., 29–31 March 1954.

5 Wilks, S. S., Van Fossan, D. D. and Clark, R. T. jr. "Chemical Analyses of Post-Mortem Tissues as Aid in Determining Physiological Status of Flying Personnel Prior to Aircraft Accidents". *Fed Proc.* **15**, 200, March 1956.

6 Air Force Regulation 160–109. Medical Service. "Medical Investigation of Aircraft Accident Fatalities". Department of the Air Force, Washington, D.C., 12 October 1956

7 Haymaker, W. E., Johnston, A. D. and Downey, V. M. "Fatal Decompression Sickness During Jet Aircraft Flight". *J. Aviat. Med.*, **27**, 2, 1956

8 Fryer, D. A. Memorandum Number 3, Joint Committee on Aviation Pathology. Armed Forces Institute of Pathology, Washington, D.C (in press).

9 Downey, V. M. Personal Communication.

10 Informal Quarterly Information Report, 1 April–30 June 1956. Aero Medical Safety Division, Directorate of Flight Safety Research, Office

of the Inspector General, Department of the Air Force, Washington, D C.

[11] STEMBRIDGE, V. A. and MOSELEY, H. G. "Analysis of 289 Gross Autopsies on Aircraft Accident Fatalities". Memorandum Number 3, Joint Committee on Aviation Pathology, Armed Forces Institute of Pathology, Washington, D C. (in Press).

[12] MASON, J. K. Personal Communication.

[13] FISHER, R. "Pathological Investigation of Navy Sea Master Accident". Memorandum Number 3, Joint Committee on Aviation Pathology, Armed Forces Institute of Pathology, Washington, D.C. (in Press).

[14] Air Force Regulation 160-35, Medical Service. "Administering Medical Treatment Facilities". Department of the Air Force, Washington, D C, 22 June 1956.

[15] Air Force Form Number 500. Department of the Air Force, Washington, D.C, 15 October 1956.

THE UNEXPLAINED AIRCRAFT ACCIDENT: SOME PROBLEMS IN POST-MORTEM DIAGNOSIS

J. K. MASON

Wing Commander, R.A.F. Institute of Pathology, Halton, Great Britain

IN recent years, the role of the pathologist in the investigation of aircraft accidents has received increasing notice (BERRY 1956). Of the various ways in which the post-mortem examination of fatal aircraft casualties can be of assistance, the detection of antecedent abnormality in the pilot is probably the most important in the apparently inexplicable accident (MASON, 1955; TOWNSEND, STEMBRIDGE and MOSTOFI, 1957). Pathological abnormalities may be of such a nature as to be incapacitating under any circumstances or may be acceptable as normal on the ground, yet shown to be dangerous at high altitude.

In this paper, it is proposed to discuss briefly three pathological conditions which seem particularly apposite to the consideration of the unexplained accident.

CORONARY DISEASE IN YOUNG ADULTS

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(SMITH and BARTELS, 1932; GLENDY, LEVINE and WHITE, 1937; SCOTT, 1938; MILLER and WOODS, 1943; FRENCH and DOCK, 1944; REICH, 1948) have drawn attention to the apparent increasing frequency of fatal disease *in younger age groups*, FRENCH and DOCK remarking that death without infarction or death with only a single occlusive lesion was perhaps more frequent in young men than in older groups. A recent review of the subject (YATER, TRAUM, BROWN, FITZGERALD, GEISLER and WILCOX, 1948) reports *the findings in 450 necropsies evolving from 866 patients*, between 18 and 39 years old, diagnosed as suffering from coronary disease; 41 per cent of those who died showed sclerotic occlusion alone without infarction. SIMPSON (1939) stated that, in a large number of accidents involving injury, *heart disease had, in fact, been the cause and*, analysing 15,000 medicolegal ... coronary or cerebral circula-

... 954),

who showed that aviators were no more susceptible to coronary disease than non-flying officers, coronary disease might well produce symptoms even in such a highly selected group as aircrew and mild anoxia might ... 1944;

... use

... rted

by BENSON (1937) and WHITE (1940); HAMMONDS (1944) reported a similar death following exposure to low pressure in a decompression chamber, and TOWNSEND *et al.* quote one accident attributed to coronary thrombosis.

However, the literature thus far reviewed deals exclusively with actual death from coronary disease and it is only comparatively recently that [illegible]

(1955) performed 300 autopsies on Korean battle casualties from which all cases in which there was a clinical history of coronary disease were excluded. Evidence of coronary arteriosclerosis was found in 77·3 per cent of the hearts with complete occlusion of one or more vessels in 3 0 per cent.

In *Table I* I have summarized the findings in the coronary arteries of 30 unselected aviation deaths. Only cases in which microscopical preparations were available have been included. For the purposes of comparison the figures obtained by ENOS *et al.* are reduced in the table so as to conform as nearly as possible to my own classification which is based on the appearances in haematoxylin and eosin stained sections, and is described in *Table I.* The incidences in the two series show a rough parallelism, though there is a considerably lower incidence of normality or near normality in my cases. It is clear that 30 cases make a poor form of comparison with 300; it is also obvious that the number of cases is too small to attempt to decide whether or not there is any essential difference between aviators and soldiers or, alternatively, between British and American military personnel. The only

TABLE I

Coronary Artery disease in healthy young adults

Present series (Aviators)			ENOS *et al.* (Soldiers)
No.	%		%
10	33 3	GRADE 0 Normal vessels or minimal Changes.	71·7
11	36 6	GRADE 1 Atheromatous plaquing leaving adequate patency.	16·0
5	16·6	GRADE 2 Atheromatous plaquing with severe restriction of lumen.	12·3 (Grades 2 and 3)
4	13 3	GRADE 3 Atheromatous plaquing with severe degenerative changes.	

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In this paper, it is proposed to discuss briefly three pathological conditions which seem particularly apposite to the consideration of the unexplained accident.

CORONARY DISEASE IN YOUNG ADULTS

The last 20 years have seen a great increase in interest in coronary disease as a cause of death in young adults. NATHANSON (1925), APPELBAUM and NICHOLSON (1935) and LEVY and BRUENN (1936) commented on the rarity of death from coronary disease below the age of 40, but many authors (SMITH and BARTELS, 1932; GLENDY, LEVINE and WHITE, 1937; SCOTT, 1938; MILLER and WOODS, 1943; FRENCH and DOCK, 1944; REICH, 1948) have drawn attention to the apparent increasing frequency of fatal disease in younger age groups, FRENCH and DOCK remarking that death without infarction or death with only a single occlusive lesion was perhaps more frequent in young men than in older groups. A recent review of the subject (YATER, TRAUM, BROWN, FITZGERALD, GEISLER and WILCOX, 1948) reports the findings in 450 necropsies evolving from 866 patients, between 18 and 39 years old, diagnosed as suffering from coronary disease; 41 per cent of those who died showed sclerotic occlusion alone without infarction. SIMPSON (1939) stated that, in a large number of accidents involving injury, heart disease had, in fact, been the cause and, analysing 15,000 medicolegal autopsies in 1947, he found that failing of the coronary or cerebral circulation accounted for more than 56 per cent of natural sudden deaths.

It would appear that, despite the evidence presented by GRAYBIEL (1954), who showed that aviators were no more susceptible to coronary disease than non-flying officers, coronary disease might well produce symptoms even in such a highly selected group as aircrew and mild anoxia might aggravate the condition (WHITE, 1940; HAMMONDS, 1944; KRITZLER, 1944; GERLIS, 1956). It follows that coronary disease in the pilot is a potential cause of aircraft accidents and "near misses" from this cause have been reported

by BENSON (1937) and WHITE (1940); HAMMONDS (1944) reported a similar death following exposure to low pressure in a decompression chamber, and TOWNSEND *et al.* quote one accident attributed to coronary thrombosis.

However, the literature thus far reviewed deals exclusively with actual death from coronary disease and it is only comparatively recently that attention has been focussed on the coronary arteries in apparently wholly healthy young adults. FITZGIBBON (1956) presented some findings in aviation fatalities in the Royal Canadian Air Force and ENOS, HOLMES and BEYER (1955) performed 300 autopsies on Korean battle casualties from which all cases in which there was a clinical history of coronary disease were excluded. Evidence of coronary arteriosclerosis was found in 77·3 per cent of the hearts with complete occlusion of one or more vessels in 3·0 per cent.

In *Table I* I have summarized the findings in the coronary arteries of 30 unselected aviation deaths. Only cases in which microscopical preparations

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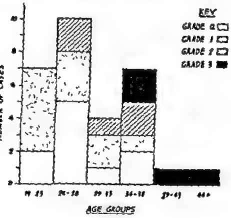
considerably lower incidence of normality or near normality in my cases. It is clear that 30 cases make a poor form of comparison with 300; it is also obvious that the number of cases is too small to attempt to decide whether or not there is any essential difference between aviators and soldiers or, alternatively, between British and American military personnel. The only

incontrovertible fact appears to be that a very high incidence of coronary abnormality can be discovered in fit young men. The majority of my cases were either pilots of jet aircraft, other operational aircrew or pilots under training; two were government employed experimental officers and two, including the only man above the age of 40, were civilians killed piloting their own light aircraft. The distribution of lesions in various age groups is shown in *Table II.*

TABLE II

AGE INCIDENCE AND SEVERITY OF LESIONS



If any of the cases in Grades 2 or 3 had, say, fallen dead in the street, a post-mortem diagnosis of death from coronary occlusion would have been perfectly justifiable in the absence of any other obvious cause. These two groups, therefore, comprise the important cases from the point of view of the unexplained accident. Limitations of space prevent an analysis of all 9 cases involved but four examples are presented which are typical.

Case 1

[illegible]

was extremely bad, and, at some 5 miles from base, he ran into the top of a hill, his number two (wing man) escaping but scything a barley field. *Figure* 1 shows the appearance in his anterior descending left coronary artery in which there is gross occlusion of the lumen with formation of a large hyalinised plaque. This case is placed in Grade 2 but his right coronary artery (*Fig.* 2) would only just achieve Grade 1 status and his left circumflex was normal by any standards.

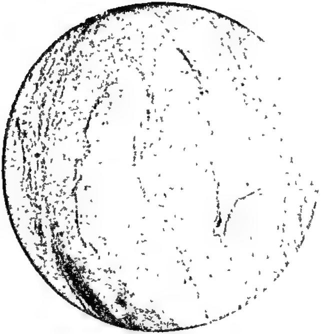


Fig 1

Fig 2

[facing page 176

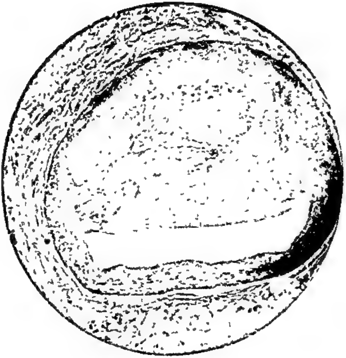


Fig 3

Fig 4

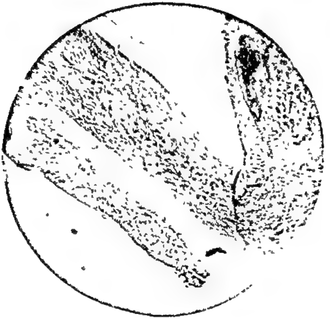


Fig 5

Fig 7

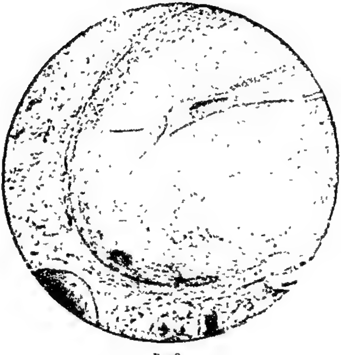


Fig 8

the top of a wooded hill. *Figure* 3 shows the gross atheromatous changes in his left anterior descending artery. There is severe narrowing of the lumen, and vascularisation and deposition of calcium place the case firmly in Grade 3. No microscopic preparations were made of his other main arteries.

Case 3

This man, aged 35, was navigator of a helicopter which crashed in bad weather. There was a conflagration and incineration of both occupants. The main left coronary artery (*Fig*. 4) shows reduction of the lumen to a mere slit, with vascularisation of the atheromatous intima. At the bifurcation of the left coronary a Y-shaped body was expelled and at first this was thought to be a true thrombus or perhaps heat coagulated blood. Microscopy shows, however (*Fig*. 5) that it was a perfect atheromatous cast of the left anterior descending and circumflex arteries, the lumen of the latter showing well in longitudinal section in the illustration. Changes in the right coronary (*Fig*. 6) were equally impressive, with patches of calcification superimposed.

Case 4

This man, aged 34, was pilot of a twin-engined bomber. A normal approach to landing was made in a moderate cross wind. Forty feet above the ground one engine failed and, despite manifest remedial action on the part of the pilot, the aircraft rolled over and crashed inverted. All the coronary arteries show very severe changes. The left anterior descending (*Fig* 7), which has been opened longitudinally, shows massive deposition of calcium, the left circumflex (*Fig* 8) shows obvious Grade 2 changes; and the right (*Fig*. 9) shows a lumen of negligible calibre.

These 4 cases all show coronary artery disease of a severity sufficient, by general medicolegal standards, to be lethal in itself. But, the general series shows that easily demonstrable atheroma is present in some two-thirds of ... come to post-mortem ... Enos's papers. Moreover, the histories of these ... acute coronary failure in ... gested that considerable ... aircraft accident on the the pilot. In ... caution is required before attemp... basis of coronary disease in the pilot.

Perforation of Peptic Ulcers

In view of the possible association between gastric ulcer and continued exposure to stress (Longstreth, 1956), pilots of operational aircraft could well be susceptible to this form of disease. Whittingham (1953) drew attention to the possibility of perforation or haemorrhages being precipitated by high altitude, and since an ulcer may well be symptomless up to the time of perforation (Card, 1952) this would seem to be a potential cause of the unexplained fatal accident and one which could only be elucidated by post-mortem examination.

Case 5

In January 1956 an interesting case was reported (Bazarnik, 1956). pilot of a single seat fighter, aged 21, breakfasted at 06 45 and took off

11.00, without further food, exercising for some 50 mins. in severe aerobatics At 12.00 he again took off, at which time he experienced severe epigastric pain. He considered an immediate landing but the pain, although present, subsided and he continued practice attacks at 25,000 ft for 30 mins. As he attempted to get out of his cockpit a very severe attack of pain struck him and he collapsed to the ground. He was admitted to hospital where operation disclosed a perforated ulcer on the lesser curvature of the stomach. Before operation, the patient denied any "gastric history", but subsequently a vague story of abdominal pain 13 and 4 months before perforation, with a possible attack of melaena 1 month previously, was elicited. He had, however, never reported sick.

A year later, the following case was seen:

Case 6

A pilot of a single seater fighter, aged 22, was leading a formation of two in a low level exercise. When breaking cloud at 1000 ft his aircraft hit the top of trees and the pilot exclaimed over the R/T. His aircraft was then seen to pull up but rolled over and crashed with the pilot still within the cockpit. The previous day, he had complained to his colleagues, but not to the Medical Officer, of vague abdominal pain and had not eaten. On the day of his death he had undertaken one sortie without breakfasting. After landing he had rapidly eaten a tin of spaghetti in the crewroom and [illegible] there was severe burning, [illegible]

The medical history in this case suggested the possibility of peptic ulcer perforation and hence a potential cause of the accident. However, the accident story itself strongly militated against such a causation; the rupture of the diaphragm indicated severe forces acting in that region; food was present only in the thorax suggesting that perforation of the stomach was not an ante-mortem phenomenon; and the microscopical preparation, while showing gross autolysis, shows no evidence of a vital ulcerative process (*Fig. 11*). There seems no doubt that this lesion was caused by fractured ribs.

Great care must also be exercised in interpreting gastric lesions when [illegible] states that [illegible] lungs may be affected. A case showing just such changes has recently [illegible] seen in a pilot who died 36 hr after an aircraft accident.

Decompression Sickness

Death from decompression sickness in aircraft is uncommon and has been reported in only three cases (Sproull, 1951; Haymaker and Johnston, 1955; Haymaker, Johnston and Downey, 1956). Two additional Royal Air Force cases have occurred. It seems possible that the paucity of post-mortem examinations in aviation fatalities has resulted in other cases being

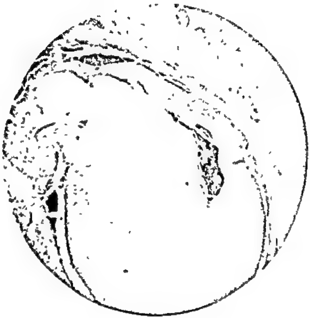


Fig 9

Fig 10

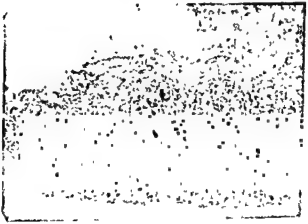


Fig 11

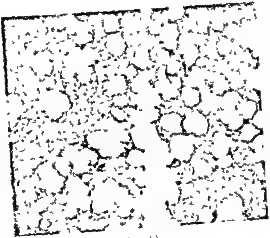


Fig. 33

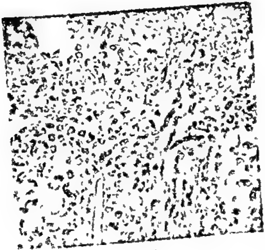


Fig. 33


Fig 15

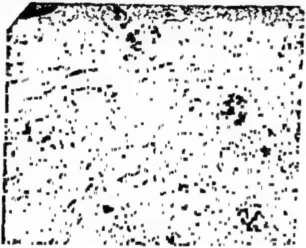


Fig 16

issed and, while the number of aircraft types in which fatal decompression hock could arise is not now great, this potential cause of unexplained accidents is present and has recently received much publicity. Death from decompression shock is easily diagnosable on clinical grounds if the condition occurs in passengers; should it occur in the pilot of a single pilot aircraft no history will be available and the diagnosis can only be made at autopsy.

The pathology of decompression sickness due to altitude has been extensively reviewed by HAYMAKER and DAVIDSON (1950); HAYMAKER and JOHNSTON (1955), HAYMAKER, JOHNSTON and DOWNEY (1956); and FRYER (1956). If the ultimate picture is complicated by extensive traumatic lesions, superimposed almost immediately after the onset of shock, the presumptive post-mortem diagnosis must rest mainly on the finding of a patent foramen ovale and widespread fat embolism.

No great significance can be attached to the finding of a patent foramen of the type seen in our second case (*Fig.* 12) as the abnormality occurs so widely (KIRKLIN and ELLIS, 1955; SCHAEFER, 1956). Moreover a patent foramen ovale does not appear to be essential to the syndrome of decompression shock.

The major interest therefore attaches to the presence of fat emboli. Pulmonary and renal fat embolism was present in both our cases to much the same degree (*Figs.* 13 and 14). Comparison with *Figs.* 15 and 16, from a case of death from fat embolism, shows that the degree in decompression sickness is moderate only. In neither of our cases was indisputable cerebral fat embolism present. In the hypothetical unexplained accident due to decompression shock, the time factors involved would seem to focus attention mainly on the degree of pulmonary fat embolism.

The conditions here may be confusing. Numerous papers (e g LEHMAN and McNATTIN, 1928; VANCE, 1931; WRIGHT, 1932), refer to the finding of pulmonary fat embolism in routine autopsies not necessarily associated with trauma. Such papers suffer, in the present context, from being largely concerned with diseased persons. It is clearly extremely difficult to produce a comparable series in healthy young adults but it was thought that the findings in aviation accidents, where death was due to multiple severe injuries and presumably instantaneous, might approximate to the normal in this type of person.

The degree of pulmonary fat embolism found in 33 consecutive fatalities is shown in *Table III*, from which all cases suspected or proven not to have died instantaneously have been excluded The table shows that some degree of fat embolism, classified on the basis of a simple grading, was present in a large proportion of these cases. Without considerable analysis, it is impossible to decide whether this is a "normal" finding. KRUCKE (1945) stated that only a very few heart beats are necessary to produce fat embolism and it is probable that many of the deaths were not truly instantaneous.

It is, however, clear from the results that an attempt to allocate an unexplained aircraft crash to decompression shock, using the presence of Grade 2 pulmonary fat embolism as a significant factor in the diagnosis, would be open to considerable error.

Table III.—Incidence of Pulmonary Fat Embolism in immediate deaths due to multiple injuries

Grade 0	No fat emboli seen	11	33 3%
Grade 1	Emboli found after some searching	12	36 4%
Grade 2	Emboli easily found	9	27·3%
Grade 3	Emboli present in large numbers	1	3 0%
Grade 4	Emboli equivalent in concentration to death from fat embolism	0	0

Conclusion

To regard the general tenor of this paper as iconoclastic would be a gross misinterpretation It is firmly believed that the pathologist has a most important role to play in the investigation of aircraft accidents. It is not for one moment denied that there are a large number of pathological conditions, demonstratable only by autopsy examination, which might arise in a pilot in flight and precipitate an aircraft accident.

Aviation pathology is, however, in its infancy and the effect of aviation on general human pathology is not yet fully understood. Of even greater im-

our present state of knowledge, caution is necessary before ascribing an unexplained accident to human pathology. The sole purpose of this paper has been to present some problems which have arisen in personal practice in this field.

Sommaire

L'un des moyens les plus importants qui permettent à l'anatomopathologiste d'aider à faire la lumière au sujet d'un accident aérien inexpliqué est la mise en évidence de certaines lésions frappant l'aviateur d'incapacité. La présente communication expose brièvement trois états pathologiques considérés comme étant en rapport avec le thème du symposium.

Maladie coronarienne des jeunes adultes

On s'est récemment intéressé de plus en plus à la maladie coronarienne comme ... *450 autopsies* ... *affec-* ... *roduire* ... *igant*

Dans ces toutes dernières années, l'attention a été concentrée, surtout par ENOS *et Coll. sur la fréquence particulière d'une maladie coronarienne démontrée par l'autopsie d'hommes jeunes chez lesquels rien, pendant leur vie, ne pouvait faire penser à une telle affection. Des signes analogues ont été constatés chez de jeunes aviateurs tués accidentellement; neuf cas sur trente non triés présentaient des modifications de la circulation coronarienne suffisamment marquées pour faire penser qu'elles ont été cause de la mort ou d'une incapacité, par conséquent cause d'accident.*

L'histoire ici rapportée de quatre des accidents qui sont tout-à-fait caractéristiques par ailleurs, permet d'éliminer cette éventualité.

En raison de ces constatations, s'ajoutant à d'autres, l'auteur est d'avis qu'une grande prudence s'impose avant d'attribuer un accident inexpliqué à une maladie coronarienne du pilote.

Perforation d'ulcère peptique

L'exposition continue aux stress que subissent les pilotes en service actif les prédispose à l'ulcère peptique qui, s'il est latent, peut aboutir à la perforation en vol. Un cas de cette sorte est décrit, mais le pilote put atterrir sans dommage et fut sauvé par une intervention chirurgicale.

Dans un accident mortel récent, il y avait des antécédents caractéristiques d'ulcère peptique et l'on trouva à l'autopsie une vaste perte de substance à l'estomac. Mais l'autopsie complète, ainsi que l'histoire de l'accident, montrèrent qu'il s'agissait non pas d'une perforation vraie, mais d'une conséquence du traumatisme terminal.

L'attention est attirée ici encore sur la nécessité d'être prudent dans l'interprétation des lésions gastriques quand la mort n'est survenue qu'un certain temps après l'accident.

Mal de décompression

[illegible]

devrait empêcher la formation d'embolies graisseuses des organes d'un système.

On admet que le foramen ovale manifeste de type valvulaire est chose trop commune pour avoir une valeur diagnostique.

Afin d'établir la signification d'un degré modéré d'embolisme graisseux pulmonaire chez les jeunes adultes bien portants, on a examiné les poumons de 33 sujets morts d'accident et triés de façon à exclure tous ceux où l'on avait une raison de penser que la mort n'avait pas été immédiate. Dans environ 30 pour cent de ces cas, on a trouvé facilement ces embolies graisseuses.

Il se peut que toutes ces morts n'aient pas été absolument immédiates, mais ces chiffres montrent qu'il serait extrêmement aventuré de prétendre attribuer un accident à un choc de décompression chez le pilote sur la seule constatation d'un degré modéré d'embolies graisseuses pulmonaires.

Conclusion

Bien que les opinions exprimées ci-dessus apparaissent quelque peu négatives, il ne faut pas en déduire que cela témoigne d'un manque de considération pour l'importance du rôle de l'anatomopathologiste dans les enquêtes sur les accidents

[illegible]

simplement quelques points particuliers des difficultés rencontrées dans la pratique personnelle de l'auteur.

References

APPELBAUM, E. and NICHOLSON, G. H. B. "Occlusive Disease of the Coronary Arteries". *Amer. heart J.* **10**, 662, 1935.

BAZARNIK, K. Personal Communication, 1956.

BENSON, O. O. "Coronary Artery Disease. Report of a Fatal Cardiac Attack in a Pilot while Flying". *J. Aviat. Med.* **8**, 81, 1937.

BERRY, F. B. "Icarus and the Physician". *J. Aviat. Med.* **27**, 197, 1956.

CARD, W. I. In *Principles and Practice of Medicine.* (L. S. P. Davidson, Ed). Edinburgh, E. & S. Livingstone Ltd., 1952.

ENOS, W. E., HOLMES, R. H. and BEYER, J. "Coronary Disease among United States Soldiers Killed in Action in Korea". *J. Amer. med. Ass.* **152**, 1090, 1953.

FITZGIBBON, G. M. "The Application of the Exercise Stress Test in Aviation Medicine". *J. Aviat. Med.* **27**, 179, 1956.

FRENCH, A. J. and DOCK, W. "Fatal Coronary Arteriosclerosis in Young Soldiers". *J. Amer. med. Ass.* **124**, 1233, 1944.

FRYER, D. I. "The Pathology of Decompression Sickness". Presented at 2nd Scientific S [illegible] Pathology 1956.

GERLIS, L. M. "Th [illegible] Atherosclerosis" [illegible]

GLENDY, R. E., LE [illegible] Youth". *J. Amer. med. Ass.* **109**, 1775, 1937.

GRAYBIEL, A. "Flying Stress and Heart Disease in U.S. Naval Aviators". U.S. Naval School of Aviat. Med. Proj. Rep. No. N M 010 059.06-10, 1954.

HAMMONDS, E. E. "[illegible] Atmospheric Pressure [illegible] 1944.

HAYMAKER, W. and [illegible] to Simulated High Altitudes in Decompression Chambers". *J. neuropath. & exper. Neurol.* 9, 29, 1950.

HAYMAKER, W. and JOHNSTON, A. D. "The Pathology of Decompression Sickness". *Milit. Med.* **117**, 285, 1955.

HAYMAKER, W., JOHNSTON, A. D. and DOWNEY, V. M. "Fatal Decompression Sickness During Jet Aircraft Flight". *J. Aviat. Med.* 27, 2, 1956.

KIRKLIN, J. W. and ELLIS, F. H. "Atrial Septal Defect". *Surg. Clin. N. Amer.* **35**, 989, 1955.

KRITZLER, R. A. "Acute high Altitude Anoxia. Gross and Histologic Observations in 27 Cases". *War Med.* 6, 369, 1944.

KRUCKE, W. "Die Fettemboli des Gehirns". *Zbl. allg. Path. path. Anat.* **83**, 67, 1945.

LEHMAN, E. P. and MCNATTIN. R. F. "Fat Embolism. II. Incidence at Post Mortem". *Arch. Surg.* **17**, 179, 1928.

LEVY, R. L. and BRUENN, H. G. "Acute, Fatal Coronary Insufficiency". *J Amer. med Ass* **106**, 1080, 1936

LONGSTRETH, H. P. "Endocrine Effects of Trauma". *Milit. Med.* **119**, 22, 1956.

MASON, J. K. "The Pathology of Fatal Aircraft Accidents". *J. clin. Path.* **8**, 348, 1955

MILLER, W. S. and WOODS, W. W "Fatal Coronary Thrombosis in a Man aged twenty-two" *Brit. heart J* **5**, 101, 1943.

NATHANSON, M H. "Disease of the Coronary Arteries" *Amer. J. Med Sci* **170**, 240, 1925

REICH, N. E. "Coronary Deaths in 'Healthy' Young Soldiers; a Clinicopathologic Study". *Amer. Practit.* **2**, 731, 1948.

SCHAEFER, J. H "Fat Embolism of the Brain, Mechanism of". *Milit. Med* **118**, 496, 1956.

SCOTT, E. G. "Coronary Thrombosis in a Twenty-seven Year Old Man". *Virginia Med Mon* **63**, 391, 1938.

SIMPSON, C. K. "Coronary Thrombosis". *Lancet* **i**, 635, 1939.

SIMPSON, C. K. "Pathology of Sudden Death". *Lancet* **ii**, 745, 1947

SMITH, H L. and BARTELS, E C "Coronary Thrombosis with Myocardial Infarction and Hypertrophy in Young Persons". *J Amer. med. Ass* **98**, 1072, 1932.

SPRC[illegible]

STRA[illegible]
Mosby Co., 1954.

TOWNSEND, F. M., STEMBRIDGE, V. A. and MOSTOFI, F. K. "The Role of [illegible]

VAN [illegible]

WHI[illegible]
a Single Seat Aircraft". *J. Amer. med. Ass* **115**, 447, 1940.

WHITTINGHAM, H E. "Medical Aspects of air Travel". *Brit med J.* **i**, 556, 1953.

WRIGHT, R B "Fat Embolism" *Ann. Surg* 96, 75, 1932.

YATER, W. M , TRAUM, A H , BROWN, W G., FITZGERALD, R. P., GEISLER, M. A. and WILCOX, B B "Coronary Artery Disease in Men Eighteen to Thirty-nine Years of Age". *Amer. Heart J.* 36, 334, 1948.

THE *POST HOC* DIAGNOSIS OF LOSS OF USEFUL CONSCIOUSNESS IN THE AIR

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IN a previous communication[1] we discussed some of the physiological and morbid circumstances which can affect "normal" aircrew in the air, and which may summate to produce varying interference with useful consciousness. We wish today to review briefly the problems presented by the *post hoc* diagnosis of such a state with its sequelae.

The maintained operation of an aircraft may demand a considerable continuum of mental attention. The inanimate machine is potentially insistent in its requirements, and even momentary lapses on the part of the operator can set in motion a chain of events which may prove consequential. In contrast to the potential requisites of flight, the normal flow of consciousness is not continuous and may vary from moment to moment. Cerebral functioning with its active moments of productive "systole", has as well periods of inattentive "diastole" which probably play a useful anabolic role.

By some quirk of nature, it so happens that the brain despite its capital role, has been designed physiologically with a minimum of reserve as compared with other tissues. This may be an inherent limitation consequent on its large metabolic requirement. The brain is highly dependent for its second-to-second functioning on the maintenance of adequate blood flow, not only to bring oxygen to the tissue but substrate as well. Brain tissue has a very poor "oxygen credit".

The integrated demands of flight on the operator are well indicated by the length of time required to train normal personnel to master the art. Probably no mechanical device is equally as demanding. When this is coupled with the fact that the nature of the occupation in many instances imposes conditions which are particularly embarrassing to the normal maintenance of flow of substrates to the brain, it is not surprising that at times these conditions may be limiting. Nature is apt not to forgive a momentary loss of consciousness under such circumstances.

Specifically, the factors we are concerned with include hypoxia, unusual acceleration, forced maintenance of posture, abnormal environmental temperature, acute vertigo, pressure breathing, decompression, possibility of hyperventilation or hypoglycaemia—the pause that refreshes in the air is difficult to effect. Carbon monoxide and other noxious gases must be considered. Sudden overwhelming psychic demands may be momentarily paralyzing. In addition, the day to day requirement for maintaining a programme entailing the disciplined and coordinated effort of many individuals may find the particular human faced with operating under any one of many pertinent but common vicissitudes which can be prejudical to

his welfare. These include alcoholic hangover, head cold, influenza,

must be considered.

Failure to maintain the perquisite consciousness is always apt to be a serious event in the air. The individual may recover in time to regain control of the aircraft, or an alternative member of aircrew may retrieve the situation. Too often it may rapidly allow the aircraft to assume an impossible condition of flight with an inevitably fatal result Both types of sequelae present themselves for our solution.

Just as the brain is timewise immediately dependent on its normal physiological supply, so also its powers to recover are rapid and relatively profound Failure of consciousness such as in a faint, can be recovered from rapidly, leaving few clues to enable a diagnosis to be made. Nevertheless there may be certain physiological or biochemical "scars" which persist

In essence, our problem presents two phases for diagnosis, namely, (I) Was there actual loss of useful consciousness on the part of the operating personnel? (II) What were the factors causing this state of affairs? The former may be important on account of its implication of fitness of the individual to fly, the latter, in regard to adequacy of training or equipment.

Limiting ourselves to conditions where loss of useful consciousness follows from interference with normal substrate flow to the brain, two main conditions arise, namely (a) Inadequacy of one or all substrates in the blood, such as are met with in hypoxic hypoxia, carbon monoxide poisoning, or hypoglycaemia (b) Inadequacy of delivery of substrates, i.e. of blood flow.

tion, such as in vasovagal syncope

In conditions which do not prove fatal, recovery from these vascular changes is apt to be relatively complete by the time the aircrew are available for examination. We are dependent, therefore, more on the associated sequelae to make the diagnosis. Where, however, events prove fatal, the abrupt arrest of circulation is liable to maintain the *status quo* enabling subsequent examination to be informative. In this event the measurement of the amount of haemoglobin or its breakdown products associated with the parenchyma of the tissues should yield valued information Such arteriolar and capillary blood supply is not only significantly variable in amount physiologically, but is relatively immune from artefacts resulting from the high accelerations imposed by the terminal impact. With modern methods satisfactory determination can be made on relatively small amounts of tissue, certainly amounts which are apt to be recovered in even the most violent disintegrations encountered. Various quantitative methods are available or can be suitably modified, including biochemical or spectroscopic analysis of extracts of tissue homogenates, histochemical examination including

histocolorimetry, or even capillary counts as measurements of patency or dilation.[2, 3]

Quantitative post-mortem measurements of the degree of blanching or engorgement occurring in the various tissues should yield pertinent diagnostic information. The same individual can be made to serve as his own

This can be indicated by a decreased ratio of the relative amount of haemoglobin in brain to that in skeletal muscles. A somewhat similar condition may be encountered in positive acceleration,[20a] but a body gradient in the muscle findings serves to differentiate this state from others associated with a generalized increase in muscle blood content, such as occurs in hyper-

1

Hypoxic hypoxia, on the other hand, produces blood shifts which differ from either of these. There is usually a vasodilation in the brain with consequently increased haemoglobin in the tissue. Conversely, there is an attempt to conserve the circulation peripherally so that vasoconstriction in the muscles ensues Muscles of the leg, therefore, would contain less haemoglobin, and the brain to muscle ratio would be increased. Carbon dioxide poisoning leads to an even greater degree of vasodilatation in brain. Conversely, breath- ... vasoconstriction[24]

5

hysio-

logically variable. There is splanchnic tissue engorgement associated with vertigo and vasovagal syncope, but the reverse is true in hypoxia, syncope from primary heart failure, or possibly acceleration.

The degree of blanching of the skin may similarly be measured post- ... is usually assoc-

ie skin.

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ARPEY-

r more

than a *few seconds, the posterior pituitary is stimulated*, secreting its hormone and causes pallor of the skin which persists for many minutes after syncope of various types. This pallor is generalized. Acceleration may show a gradient in skin haemoglobin concentration as with the muscles of various parts of the body, or conversely, a marked increase associated with the suffi *sion which occurs after the acceleration has passed off.* Findings must alwa be interpreted in the light of the flight history.

... post-mortem micro-examination

for ... vasoconstrictio

or ... disintegratio

immediately *post mortem* actually increases the reliability of the result Furthermore, at the crash site, other things being equal, the farther the tissu is found from the site of impact, the less the interference from termina

acceleration is liable to be, the force developed being inversely proportional to the distance over which the deceleration is spread.

When there is actual loss of consciousness there is usually associated a loss of muscle tone resulting in failure to maintain an erect posture. If the head is already hanging forward at the time of impact, the line of fracture of the helmet or skull may be determined thereby. If on the other hand the individual is seated erect, there would be a greater likelihood of a more fore

[illegible]

isms to be elicited, the situation being determined by the tonus of the muscles already in existence at the time of impact Other systems might be investigated in the light of similar considerations

In addition to the shifts in the distribution of blood elements associated with various factors playing a role in interference with consciousness during flight, other metabolic shifts may be considered

As an example, we have had some success in developing a method for

[illegible]

therefore, are able to manifest themselves. It is well known that as a defence against hypoxia the body tends to contract itself into a heart-lung-brain organism while at the same time other tissues provide metabolic substrates which act to maintain these essentials. Brain normally metabolizes glucose from the blood stream to carbon dioxide and water, but in lieu of oxygen, it exhibits a well developed ability to obtain energy by glycolysis In the brain the end product of the latter change is lactic acid. During hypoxia there is a mobilization of substrates from various sources which are brought to the brain and which can undergo this anoxic breakdown When, therefore, we measure the total lactic acid concentration in the brain tissue *post mortem*, that is the preformed and that formed from existing substrate after death,

[illegible]

altitude, drowning, acute oedema of lung, or primary respiratory failure. Hyperventilation, possibly due to the reduced blood flow locally to brain, does not apparently interfere with the test, nor does carbon monoxide

[illegible]

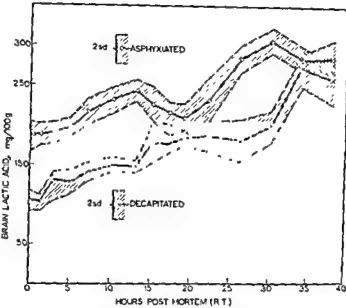

Fig. 1. Influence of pre-mortem anoxia on brain lactic acid in mice.

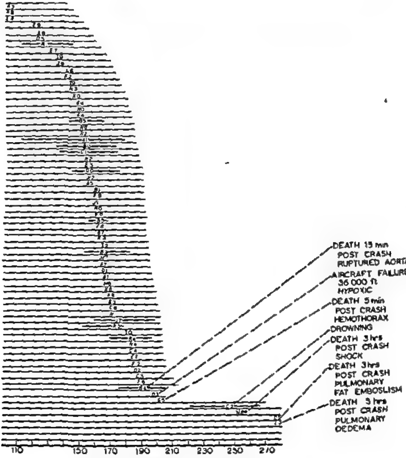

Fig. 2. Hypoxia test, brain lactic acid

Fig 3

A further limitation of the method arises from the length of time required for the body to mobilize the products required to give a positive test. These limits are well illustrated in *Fig.* 4 where the results from two individuals following a mid-air collision at altitude are shown. The one pilot managed to ride his aircraft to a low altitude before it went into an uncontrolled dive, presumably due to mechanical failure. His brain lactic acid showed 157, 163, 159 mg/100 g. The pilot of the other aircraft ejected himself at an

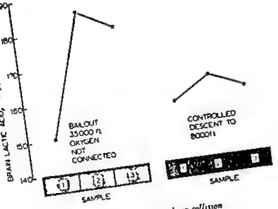

Fig 4 *Hypoxia test, mid-air collision*

altitude of 35,000 ft, but was found not to have his emergency oxygen connected. He apparently failed in his drill, his parachute being released before abandoning his seat and failed to deploy. The brain lactic acid noted in this case was 150, 185, 180 mg/100 g. By taking these aliquot samples across the section of the sample, some measure of possible post-mortem oxidation or conversely, of contamination from without, can be secured. These simultaneous results when compared, are thus in keeping with the latter pilot having experienced a disabling hypoxia four or five circulation times prior to cessation of circulation on impact with the ground It is thus evident that the method can provide useful evidence but always must be interpreted in the light of the history of the particular case

Many other post-mortem findings warrant attention. Acute severe hypoxia may result in vomiting or incontinence Gastric secretion is in creased in vertigo, and biochemical and microscopic evidence of this shoul be sought. In pressure breathing there may be an embarrassing amount oxygen swallowed which rapidly comes into equilibrium with the other gas of the body and persists [17a, 17b, 19a, 19b, 20b, 32b] The amount of food in t stomach and intestinal tract should be noted in relation to hypoglycaem High glucose content especially should be looked for.

If vestibular stimulation has existed for any length of time previous death, there may be varying evidence of labyrinthine oedema or inflam tion[21] Trauma at the time of body disintegration does not result in blee

into the tissues. Vertigo likewise is generally associated with increased salivation. This may be evidenced by buccal examination, and the parotid cells examined by periodic acid staining for lysis of granules adjacent to the lumen of the duct.

In hyperventilation the post-mortem onset of rigor is rapid. There may be indications of carpopedal spasm deduced from evidence indicating the relative attitude of the fingers at the time of impact.

Evidence of the patency of the foramen ovale should always be noted in connexion with aeroembolism. Similarly, incapacitating cerebral embolism may be initiated in the caput and superior sinuses of the brain from a combination of positive acceleration and decompression. Fixation under reduced [illegible]

of a compensatory vasodilatation, which lasts for an hour or more.

Carbon monoxide poisoning can be determined *post mortem* by the examination of various tissues according to the method of CLARK *et al.*[22]

There is at least experimental evidence that an interstitial myocarditis may be localized by hypoxia during intercurrent (virus) infections.[4]

In the fortuitous circumstance where the loss of useful consciousness does not prove fatal, a rare opportunity for diagnosis presents itself. While the physician seldom can be present to observe the attack first hand, much can be gained from a close history, particularly if the aircrew have been previously briefed on the possible limitations and behaviour of the normal human body under such circumstances.[5]

Recognizing that medical examination will usually have to be *post hoc*, particular attention should be directed towards those findings which tend to give an integrated result thus indicating immediate past performance. Such conditions are met by various secretions of the body. In addition to the [illegible]

The urine collected in the bladder provides a valuable integrated measure of the occurrence of hyperventilation. Acapnia results in a prompt increased secretion of base coupled with a reduced secretion of ammonia. Blood lactic acid is apt to be increased.

Ketosis and ketonuria in the presence of an alkalosis is practically pathognomonic of hyperventilation under our conditions. There is however need for more information as to the rapidity of development of this *useful finding* under conditions as met in flight.

SMITH of Farnborough has found some interesting changes associated with *hypoxia in* urinary substances eluted after charcoal adsorption when examined chromatographically. Loss of pressurization at altitude is liable to give rise to varying degrees of dehydration with consequent changes in specific gravity. During hypoglycaemia a diminution of urinary noradrenalin [illegible] of adrenalin has been reported.[6]

[illegible] [11, 14] whereas

[illegible] s the *reverse*

effect.[9, 13] The control of water secretion in the urine is influenced by the

secretion of antidiuretic hormone from the posterior pituitary Due to the time relationship involved, this phenomenon particularly warrants attention, since activity of the hormone can be detected for some hours after its elaboration The volume, hydrogen ion concentration, and specific gravity of the urine voided immediately at the time of initial examination should be noted and a test for antiduretic activity instigated immediately.[9] Useful information can be gained by plotting the curve of urinary volume collected at half-hourly intervals for the ensuing 4 hr after ingestion of suitable amounts of water as shown by the results of BRUN *et al* [10] in *Fig.* 5, and.[12] A

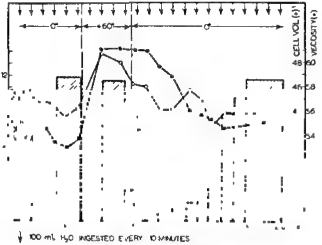

Fig 5 *Experiment showing oliguria and hemoconcentration after a brief syncope (after* BRUN, KNUDSEN *and* RAASCHOU[9] [10], 1946)

delayed [illegible]

following periods of anoxia or hyperventilation *per se* with or without acapnia.[14] Negative acceleration or positive acceleration when protected with a *G* suit may produce similar effects.

It must be realized, however, that antidiuretic hormone secretion is not pathognomonic of any of the above conditions, but can occur following psychic trauma, etc.[13] However, it is a constant finding associated with syncope

[illegible]

into the tissues Vertigo likewise is generally associated with increased salivation. This may be evidenced by buccal examination, and the parotid cells examined by periodic acid staining for lysis of granules adjacent to the lumen of the duct.

In hyperventilation the post-mortem onset of rigor is rapid There may be indications of carpopedal spasm deduced from evidence indicating the relative attitude of the fingers at the time of impact.

Evidence of the patency of the foramen ovale should always be noted in connexion with aeroembolism. Similarly, incapacitating cerebral embolism may be initiated in the caput and superior sinuses of the brain from a combination of positive acceleration and decompression. Fixation under reduced pressure is useful to bring out an otherwise occult aeroembolism.[19]

Of interest in this connection is the recent finding of DUFF *et al.*[23] that arterial aeroembolism results in an *increased* blood flow presumably by way of a compensatory vasodilatation, which lasts for an hour or more.

Carbon monoxide poisoning can be determined *post mortem* by the examination of various tissues according to the method of CLARK *et al.*[22]

There is at least experimental evidence that an interstitial myocarditis may be localized by hypoxia during intercurrent (virus) infections.[4]

In the fortuitous circumstance where the loss of useful consciousness does not prove fatal, a rare opportunity for diagnosis presents itself. While the physician seldom can be present to observe the attack first hand, much can be gained from a close history, particularly if the aircrew have been previously briefed on the possible limitations and behaviour of the normal human body under such circumstances.[5]

Recognizing that medical examination will usually have to be *post hoc*, particular attention should be directed towards those findings which tend to give an integrated result thus indicating immediate past performance. Such conditions are met by various secretions of the body. In addition to the urine, these include sweat, saliva, lachrymal, nasopharyngeal, bronchogenic, and gastric secretions which can readily be examined and whose character varies according to circumstance.

The urine collected in the bladder provides a valuable integrated measure of the occurrence of hyperventilation. Acapnia results in a prompt increased secretion of base coupled with a reduced secretion of ammonia. Blood lactic acid is apt to be increased.

Ketosis and ketonuria in the presence of an alkalosis is practically pathognomonic of hyperventilation under our conditions. There is however need for more information as to the rapidity of development of this useful finding under conditions as met in flight.

SMITH of Farnborough has found some interesting changes associated with hypoxia in urinary substances eluted after charcoal adsorption when examined chromatographically. Loss of pressurization at altitude is liable to give rise to varying degrees of dehydration with consequent changes in specific gravity. During hypoglycaemia a diminution of urinary noradrenalin [illegible] reported.[6] [illegible][14] whereas [illegible] the reverse effect.[9, 13] The control of water secretion in the urine is influenced by the

secretion of antidiuretic hormone from the posterior pituitary. Due to the time relationship involved, this phenomenon particularly warrants attention, since activity of the hormone can be detected for some hours after its elaboration. The volume, hydrogen ion concentration, and specific gravity of the urine voided immediately at the time of initial examination should be noted and a test for antidiuretic activity instigated immediately.[9] Useful information can be gained by plotting the curve of urinary volume collected at half-hourly intervals for the ensuing 4 hr after ingestion of suitable amounts of water as shown by the results of BRUN *et al*[10] in *Fig.* 5, and [12] A

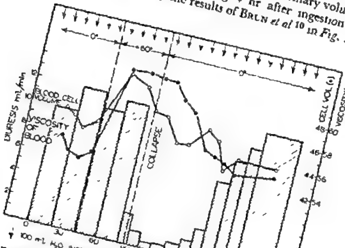

Fig 5 Experiment showing oliguria and hemoconcentration after a brief syncope (*after* BRUN, KALDSEN and RAASCHOU[10], 1946)

delayed excretion curve indicates the probability of an elaboration of antidiuretic hormone An increased secretion of antidiuretic hormones is found in syncope of various types[9, 13] vertigo,[12] or following pressure breathing[11] Conversely, a decreased antidiuretic hormone effect may be anticipated following periods of anoxia or hyperventilation *per se* with or without acapnia[14] Negative acceleration or positive acceleration when protected with a *G* suit may produce similar effects.

It must be realized, however, that antidiuretic hormone secretion is not pathognomonic of any of the above conditions, but can occur following psychic trauma, etc.[13] However, it is a constant finding associated with syncope.

The elaboration of antidiuretic hormone following syncope with or without associated convulsions can be particularly valuable in the differential diagnosis from epilepsy where no such hormone elaboration is usually found[18]

Skin secretions can also provide integrated evidence of previous changes in physiological state. The physiology and biochemistry of skin has recently been reviewed[7] Secretions can be studied from direct examination of the

skin surface, from skin washings, or from extractions of clothing in contact with the skin. There is evidence that apocrine secretion is adrenergic in response, in contrast to eccrine sweating which is predominantly cholinergic, This difference should prove useful. Apocrine sweat may be easily demonstrated due to its fluorescence under ultraviolet light (in the axilla, for example). Eccrine sweating due to emotional strain is more liable to occur in the palmar and plantar areas that is heat invoked sweating. In stress situations the sodium to potassium relationship is modified in the sweat, reflecting the electrolyte dysbalance in the blood.

Objective evidence for alcoholic hangover may also be obtained from skin response. KUNO[8] reported that the critical sudoriferous environmental temperature dropped significantly on the day following a drinking bout

There is evidence which indicated that adrenergic states can interfere with the action of antidiuretic hormone.[13] If this is suspected, evidence of apocrine (adrenergic) sweating should assist in the interpretation of the findings.

Gastric secretions can be influenced by many factors related to our problems. Anger, resentment or anxiety may lead to vagotonic response with increased acidity, peptic activity and gastric motility.[15] Similarly, in hypoglycaemia there is increased hydrochloric acid and pepsin secretion Proof of this condition is indicated by a localized hyperaemia of the mucous lining. Conversely, fear or depression may produce the reverse effect both with reduced acid and peptic secretion, associated with blanching of the mucosa. The vasomotor changes are usually similar to the flushing or pallor of the face. As pointed out by POWELL,[16] anger or resentment was a common prodromal finding associated with our series of established loss of consciousness *in the air*.

Increased serous nasal secretion is the rule associated with engorement of the nasal mucous membrane in the presence of extreme cold, such as can occur from loss of coupe top at altitude. Nasal drip into the mask can be quite embarrassing under the circumstances and leaves it mark In the last part of his paper (not published here) the author emphasizes the urgency of prompt material observation when the episode has not proved fatal

SOMMAIRE

Revue génerale et commentaires sur l'interprétation de toutes les recherches qui peuvent aider à résoudre le problème diagnostique de la perte de connaissance en vol, lequel comprend en réalité deux stades:

(I) Y a-t-il eu réellement perte de connaissance?

(II) Quels ont été les facteurs déterminants de cet état de choses?

L'auteur examine successivement le dosage d'hemoglobine, l'état d'irrigation des tissus, l'état du tonus musculaire (interprétation des fractures du crâne), le diagnostic d'hypoxie par dosage de l'acide lactique dans le tissu cérébral—enfin les vomissements, l'incontinence, la congestion vestibulaire, les signes d'intoxication oxycarbonée et alcoolique, l'examen des urines et des secretions cutanées.

D'une façon générale une grande prudence doit présider à l'interprétation de ces données.

Dans la dernière partie de son travail (non reproduite ici) l'auteur souligne l'urgence d'une prompte observation médicale dans les cas non suivis de mort.

References

[1] FRANKS, W. R "The Summation of physiological Factors Leading to Incidents in the Air". Eighth AGARD Aeromedical Panel Meeting, May, 1956.

[2] (a) CRAIGIE, E. H.
(b) ALEXANDER, L. and PUTNAM, T J
"The Circulation of the Brain and spinal Cord". Assoc. for Res in Nerv. and Ment. Disease XVIII, pp 3, 471, 1938.

[3] LISON, L. *Histochimie et Cytochimie Animales* Gauthier-Villars, Paris, 1953.

[4] "Interstitial Myocarditis" *Lancet*, March 17, p. 328, 1956

[5] FRANKS, W R. "Physiological Near Miss" *RCAF Flight Comment*, Sept-Oct, 1955.

[6] "Cause of hypoglycaemic Symptoms" *Lancet*, June 9, p. 899, 1956.

[7] ROTHMAN, S. *Physiology and Biochemistry of the Skin* Univ Chicago Press, 1954

[8] KUNO, Y *The Physiology of Human Perspiration* London, J and A. Churchill, 1934.

[9] BRUN, C., KNUDSEN, E. O E and RAASCHOU, F "Post-syncopal Oliguria". *Acta med. scand* 122, p. 381, 1945.

[10] BRUN, C., KNUDSEN, E O E. and RAASCHOU, F "Kidney Function and circulatory Collapse. Post-syncopal Oliguria". *J. Clin Invest* 25, p 568, 1946.

[11] GAUER, O. H, HENRY, J. P, SIEKER, H. O and WENDT, W. E "The Effect of negative Pressure Breathing" *J Clin Invest.* 33, p 287, 1954

[12] TAYLOR, N. B. G, JOHNSON, W. H and HUNTER, J (Personal communication). Defence Research Medical Laboratories, Toronto, Canada.

[13] NOBLE, R L and TAYLOR, N. B G "Antidiuretic Substances in human Urine after Haemorrhage, Fainting, Dehydration and Acceleration". *J. Physiol.* 122, p 220, 1953.

[14] SIEKER, H. O, GAUER, O H and HENRY, J P. "Negative Pressure and Kidney Function". *J Clin Invest.* 33, p. 572, 1954.

[15] BEST, C H. and TAYLOR, N. B *The physiological Basis of Medical Practice* Williams & Wilkins, Baltimore, 6th Ed. p 508, 1955.

[16] POWELL, T. J. "Episodic Unconsciousness in Pilots During Flight". *J Aviat. Med.* 27, 301, 1956

[17] (a) HALL, A L "Involuntary Hyperventilation During Pressure Breathing at 43,000 feet" U S Naval Air Station, Pensacola, Project No. NM001 059 21 01, 1952
(b) MURRAY, J. H. (Personal Communication) RCAF Institute of Aviation Medicine, Toronto, Canada

[18] SHARPEY-SCHAFER, E P "Syncope". *Brit. M. J.* March 3, p. 506, 1956.

[19] SCHUBERT, W. "Uber erhöhten Gasgehalt im Hirngewebe " *Virchows Arch.* pathol, 327, p. 697, 1955.

[20] JASPER, H. *et al.* " Physiology of the Circulation of the Brain". Report Literature, 1938–1952. *Physiol. Rev* , **36**, Suppl. No. 2, 1956.
(b) ADELMAN, *et al. ibid*, 1948.

[21] DIX, M. R. and HALLPIKE, C. S. "The Pathology, Symptomatology and Diagnosis of Certain Common Disorders of the Vestibular System". *Proc. R. Soc. Med.*, **45**, p. 341 (June), 1952.

[22] WILKS, S S., VAN FOSSAN, D. D. and CLARK, R. T. "Chemical Analyses of Post-mortem Tissue as Aid in Determining Physiological Status of Flying Personnel prior to Aircraft Accidents". *Fed. Proc.*, **15**, No 650, p 200, 1956.

[23] DUFF, F., GREENFIELD, A. D. M. and WHELAN, R F. "Vasodilatation Produced by Experimental Arterial Gas Embolism in Man". *Lancet*, Aug. 1, p. 230, 1953.

[24] LAMBERTSEN, D. J., KOUGH, R. H, COOPER, D. V., EMMEL, G. L., LOESCHCKE, H H and SCHMIDT, C. F. "Oxygen Toxicity. Effects in Man of of Oxygen Inhalation at 1 and 3·5 atmospheres upon Blood Gas Transport, Cerebral Circulation and Cerebral Metabolism". *J. appl. Physiol.* **5**, p. 471, 1953.

[25] MILES, S. "Oxygen Syncope". Medical Research Council Report R N P. 57/880, U.P.S. 161, 1957.

IV. IN FLIGHT PROTECTION

LE VÊTEMENT PRESSURISÉ FRANÇAIS

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Introduction

Un des problèmes les plus aigus que posent les avions modernes actuels est celui de la protection de leur équipage contre les effets de l'abaissement considérable de la pression atmosphérique existant à l'altitude qu'ils sont susceptibles d'atteindre. De nombreux prototypes français peuvent, d'ores et déjà, dépasser largement 15,000 m et seule l'absence d'un équipement de secours approprié avait empêché les essais de ces appareils à très haute altitude

Les cabines étanches permettent de maintenir une pression pour laquelle la protection contre l'anoxémie peut être aisément assurée avec les inhalateurs d'oxygène actuels Mais alors, en haute altitude, l'aviateur est exposé à un danger grave en cas de perte de pressurisation plus ou moins brusque en raison des pressions extrêmement réduites qui existent à l'extérieur de la cabine.

L'utilisation des régulateurs à surpression permet de réaliser une protection valable jusqu'à 15,000 m, mais pour des temps extrêmement courts à cette altitude

La surpression d'oxygène délivrée par ces régulateurs a dû en effet, être limitée aux environs de 30 mm Hg pour des raisons mécaniques et surtout *physiologiques. Il est impossible d'éliminer totalement les fuites au niveau* du masque dès que l'on atteint des surpressions de l'ordre de 20 mm Hg. En ce qui concerne les troubles physiologiques, il ne peut être question ici que de les résumer, mais ils sont importants à connaitre, car c'est de leur étude qu'est dérivé le vêtement pressurisé.

Rappel Physiologique

Une surpression d'oxygène supérieure à 30 mm Hg, exercée sur le système respiratoire à l'aide d'un masque couvrant la bouche et le nez, fait naitre rapidement des douleurs au niveau des yeux et des oreilles. Ces douleurs disparaissent lorsque la surpression est réalisée non plus seulement au niveau des voies respiratoires, mais aussi sur la région céphalique tout entière. On peut réaliser cette surpression grâce à un casque étanche englobant toute le tête.

Mais, même lorsqu'un casque adequat est mis en oeuvre, il reste à lutter contre les effets de la surpression sur les poumons et la cage thoracique d'une part, sur le reste du corps d'autre part En effet une première question se pose, c'est de savoir à quelle surpression peuvent résister les poumons sans rupture. Des expériences réalisées sur l'animal ont permis de constater que les poumons se déchirent entre 40 et 60 mm Hg de surpression si la cage thoracique n'est pas protégée. Par contre, si on maintient fermement celle-ci

par un moyen de contention tel que des bandes inélastiques ou un gilet pneumatique, des pressions allant jusqu'à 170 mm Hg sont supportées sans lésions.

Une contre pression excellente peut être réalisée chez l'homme par un

Jerkin anglais) une respiration en surpression élevée est relativement aisée.

Les expériences menées chez l'homme ont montré qu'avec un casque pressurisé et un gilet pneumatique ne recouvrant que la cage thoracique, la respiration en surpression n'était tolérable que pendant 20 à 30 min à

us longs et

ADGER ont montré que sur 50 sujets, 45 pouvaient résister sans perdre connaissance à une surpression de 78 mm Hg pendant 7 min 30 sec. Mais pour des surpressions supérieures la perte de connaissance survient de plus en plus rapidement au fur et à mesure que la pression augmente.

De nombreux auteurs se sont attachés à rechercher le mécanisme de ces troubles. Ce sont, en particulier. BARACH, FENN, OTIS, RAHN, CHADWICK, HENRY, ERNSTING et, en France, GRANDPIERRE et VIOLETTE; ces auteurs ont mis en évidence l'importance des troubles circulatoires qui peuvent aboutir à la perte de conscience.

L'élévation de la pression intra-pulmonaire provoque une élévation de la pression veineuse centrale qui devient supérieure à la pression veineuse périphérique La circulation veineuse en provenance des membres s'arrête alors que le sang continue à y affluer. Celui-ci s'accumule alors dans les

Au bout d'un

ou cet état d'équilibre est atteint, il s'est produit un véritable stockage de sang dans les vaisseaux des membres. La quantité de sang ainsi stockée dans les membres a pu être mesurée expérimentalement par plétysmographie. C'est ainsi que pour une surpression de 60 mm Hg, et avec une contre pression réalisée sur le tronc tout entier, le sang accumulé dans les membres représente approximativement 260 cm^3. A cette perte de sang par stockage s'ajoute une perte de plasma par filtration à travers les parois des capillaires, cette fuite liquidienne a lieu sous l'effet de l'élévation de la pression hydrostatique. Elle a pu être chiffrée par plétysmographie, mesure du volume du sang circulant et par l'hématocrite; dans le cas d'une surpression de 60 mm de Hg cette filtration atteint 68 cm^3 par minute. Un calcul simple montrerait que dans ce cas, les volume sanguin total perdu pour le circulation serait de 500 cm^3 au bout de 3·5 min.

A ces troubles, il faut encore ajouter une baisse corrélative de la pression

élévation de la

ut améliorer la tolérance à la respiration en surpression élevée il est nécessaire d'empêcher les troubles de la circulation dans les membres Une solution simple consiste

nembres supérieurs et les pieds. Il est alors possible de résister ons d'oxygène nécessaires pour atteindre l'altitude de 20,000 m, de tolérance demeure court et ne peut guère dépasser 1 min le.

la plus satisfaisante consiste à exercer une contrepression sur entier. Cette contre-pression est réalisée par la combinaison

d'Études de Biologie Aéronautique avait mis à l'étude en une combinaison pressurisée basée sur le principe utilisé par D Lamport (levier pneumatique) pour sa réalisation de la anti-G dénommée PLS C'est également le système employé ses collaborateurs pour la combinaison pressurisée américaine. 3, des résultats très encourageants avaient été obtenus L'étude des questions de crédits fut reprise en Novembre 1954, et en la première montée à 20,000 m fut réalisée au caisson dans des tisfaisantes. Depuis de nombreux essais ont été faits et l'en- sensiblement amélioré.

ON SUCCINCTE DU VÊTEMENT PRESSURISÉ FRANÇAIS

pressurisé se compose de trois éléments principaux

ement de corps (combinaison pressurisée)
ement de tête (casque pressurisé)
ement pneumatique (régulateurs).

corps

aison pressurisée se présente comme un vêtement étroitement corps. Elle est fabriquée dans un tissu nylon-coton très résistant orosité assure une ventilation suffisante

nettre de l'enfiler facilement, des fermetures éclair sont disposées es, les avant-bras, le dos, les mollets

ture éclair disposée transversalement sur l'abdomen, permet de plis qui se forment inévitablement en position assise lorsqu'elle a position debout est plus confortable

es disposés le long des membres et de chaque côté du tronc in ajustement précis de la combinaison à son utilisateur

de tissu caoutchouté courent le long des bras, des jambes et de *du dos. Ces tubes sont reliés au tissu de la combinaison* par des s croisés. Lorsque l'on gonfle les tubes, ceux-ci tirent sur les exercent à leur tour une traction sur le tissu de la combinaison, si une contre-pression mécanique sur tout le corps (sauf la tête, les pieds)

la pression soit uniforme la section des tubes est en rapport on du corps correspondante. Après essais de différentes formules, retenu les rapports de section tels que le rapport des pressions es et la pression exercée par la combinaison sur le corps soit en 1/4. Cependant, le rapport entre la section des tubes et la rps ne suit pas une loi simple, en raison de l'inégalité de l'élasticité

des différents tissus du corps humain: c'est pourquoi il nous a semblé préférable, pour la mise au point de déterminer empiriquement les sections des tubes par la mesure des pressions exercées par la combinaison sur les différents points du corps.

Les tubes de pressurisation de la combinaison sont réunis au régulateur par un embout identique à celui de la combinaison anti-G, mais pour éviter toute confusion avec le tube de mise en pression de la combinaison anti-G, c'est ici l'embout femelle qui est fixé sur le tube de la combinaison.

La combinaison présente pour la fixation des cables de retenue du casque un anneau dorsal et une sangle thoracique.

Le col de la combinaison, muni d'un laçage, vient recouvrir la partie inférieure de la cagoule de toile de l'équipement de tête.

Un certain nombre de sujets présentant des douleurs au niveau des anneaux inguinaux ou de l'abdomen au cours de la respiration en surpression, on assure une contre-pression meilleure au niveau de cette région par une vessie inguino-abdominale mise à la même pression que le casque pressurisé par un tube connecté à l'arrivée d'oxygène du casque.

La combinaison pressurisée se porte par-dessus un sous-vêtement de soie en général, composé d'un gilet à manche longue et d'un caleçon long Ce sous-vêtement permet à la combinaison de mieux glisser et de ne pas blesser la peau.

La combinaison pressurisée elle-même, doit être considérée comme un sous-vêtement. On porte, par dessus, une combinaison de vol isolante protégeant contre le froid et le vent relatif au moment de l'éjection par exemple, et éventuellement une combinaison ventilée placée entre la combinaison de protection et la combinaison pressurisée.

La combinaison pressurisée ainsi définie peut également servir à la protection contre les accélérations soit par l'adjonction de vessies analogues à celle de la combinaison anti-G G-4A; soit en prévoyant un système de doubles tubes à la partie inférieure de la combinaison de telle sorte qu'en cas d'accélération seule la partie inférieure de la combinaison exerce une pression proportionnelle à l'accélération.

On peut également adjoindre à la combinaison pressurisée telle que nous venons de la voir un gilet pneumatique respiratoire, placé sous la combinaison, qui améliore de façon notable la respiration.

Équipement de tête

Le casque pressurisé que nous présentons n'est qu'un modèle de pré-série, basé sur le même principe que le casque américain K-1, mais dont i diffère par de nombreux détails. Il se compose.

(I) d'une armature métallique munie d'un joint creux en caout chou assurant l'étanchéité au niveau de la visière

(II) d'une cagoule de caoutchouc fixée sur cette armature et termin au niveau du cou par un repli en forme d'U assurant l'étanchéité à niveau

(III) d'une cagoule de nylon empêchant la distension de la cagoule caoutchouc et ajustée à la tête de l'utilisateur par un système de laça Cette cagoule de toile s'ouvre largement par une fermeture éclair média

(IV) d'une visière en matière plastique s'adaptant à l'armature métallique et sur laquelle se trouvent

—l'arrivée d'oxygène
—une soupape inspiratoire
—une soupape expiratoire compensée

(V) d'un ensemble micro-écouteurs permettant une liaison radiotéléphonique normale.

(VI) d'un casque anti-choc s'adaptant à l'armature métallique par des tourniquets et solidement relié à la combinaison par un système de cables en acier et de roulettes. Ce système est nécessaire pour éviter le déplacement vers le haut de l'ensemble de tête sous l'effet des fortes surpressions d'oxygène.

Le tube d'arrivée d'oxygène au masque est terminé par un embout disconnect normal qui vient se mettre en place sur un bloc de trois ou quatre voies Les trois autres embouts de ce bloc correspondent

—à l'arrivée d'oxygène du régulateur de bord,
—à l'arrivée d'oxygène du régulateur de secours,
—au départ de l'oxygène vers les vessies inguino-abdominales et éventuellement un gilet pneumatique respiratoire.

Cet équipement ayant révélé quelques défauts importants espace mort trop important, impossibilité d'enlever la visière au-dessous de 3000 m, visibilité latérale pratiquement nulle lorsque la pression à l'intérieur dépasse 50 mm Hg, il a été décidé de réaliser un autre équipement de tête obviant à ces défauts Le nouveau casque, dont l'expérimentation a commencé, est caractérisé par la présence d'une visière pivotant sur la partie supérieure du casque et d'un masque permettant au pilote de garder la visière levée tant que son altitude de vol ne dépasse pas 12,000 m.

Équipement pneumatique

Pour que l'équipement donne au pilote le maximum de confort, il est absolument indispensable que la pression dans le masque et la pression sur le corps soient égales. Il a donc paru intéressant de réguler ces deux pressions par le même organe de façon à obtenir un synchronisme parfait Cet organe est désigné "relais pneumatique"

Relais pneumatique (*Fig.* 2 A)

Un détendeur altimétrique—gonfle les bourrelets à la pression convenable et, à leur tour, les bourrelets règlent la pression des régulateurs d'oxygène.

Une valve altimétrique—mettant les bourrelets à l'air libre du sol à l'altitude 11,700 m, point de départ de la courbe du régime de surpression.

Un détendeur 6 *HPz*—pour alimentation de régulateur de bord

Le relais comporte également·

—un raccord pour prise de pression 150 HPz destiné à alimenter le manomètre de contrôle des pressions bouteilles,
—un raccord pour prise de pression 6 HPz pour alimentation de régulateur de bord,
—un raccord pour réglage de la surpression du régulateur de bord,
—un raccord pour alimentation des bourrelets,
—une soupape de sûreté.

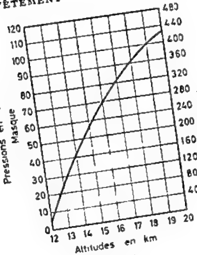

Fig 1

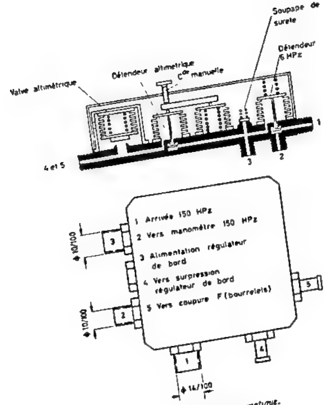

Fig 2 A—*Relais pneumatique.*

Régulateur de Bord type 218 (*Voir Fig* 3 B)

C'est un régulateur Bendix D-2 modifié de façon à lui permettre de réaliser les nouvelles courbes de surpression. Sans entrer dans le détail des modifications qui sont assez complexes, nous indiquerons simplement que la pression des boudins vient agir sur une membrane de section *s*. Cette membrane réagit à son tour sur la membrane respiratoire *S*.

$$\text{On doit avoir}. \frac{S}{s} = \frac{\text{Pression bourrelets}}{\text{Pression masque}}$$

Le régime surpression n'entre en action qu'à l'altitude 11,700. Du sol, à cette altitude, le régulateur fonctionne exactement comme un appareil non modifié

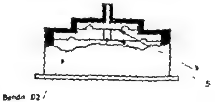

Fig 3. B—*Régulateur Vergne type* 218.

Régulateur de secours Vergne type 241 (*Voir Fig.* 4)

Ce régulateur fait partie de l'équipement individuel du pilote. Il est monté sur une bouteille d'oxygène de 0·800 l C'est un appareil à la demande, débitant de l'oxygène pur à la surpression demandée.

Il comporte :—

1 manomètre indiquant la pression de la bouteille,

1 détendeur,

1 raccord de chargement équipé d'un clapet anti-retour,

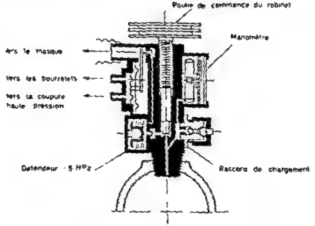

Fig 4 C—*Régulateur Vergne type* 241.

1 valve respiratoire pour inhalation à la demande,

1 robinet à deux poulies s'ouvrant soit à la main, en cas de défaillance du régulateur de bord, soit automatiquement en cas d'éjection.

Cet appareil ne doit en principe être mis en service qu'en cas de secours. Il peut cependant remplacer le régulateur de bord, sans toutefois réaliser comme le Vergne 218, la dilution jusqu'à 10,000 m.

La surpression masque est assurée comme pour le régulateur de bord par une membrane de réduction venant agir aur la membrane respiratoire.

Accessoires (*Voir Fig.* 5). L'équipement pneumatique est complété par trois accessoires:

Un raccord à 4 voies monté sur les canalisations respiratoires, comportant:

—une sortie vers le masque,

—une sortie vers le régulateur 241,

—une sortie déconnectable grosse section, vers le régulateur de bord,

—une sortie déconnectable petite section, vers la poche inguinale.

—un raccord à coupure basse-pression, monté sur le siège éjectable.

—un raccord à coupure haute-pression comportant deux clapets anti-retour, également monté sur le siège éjectable.

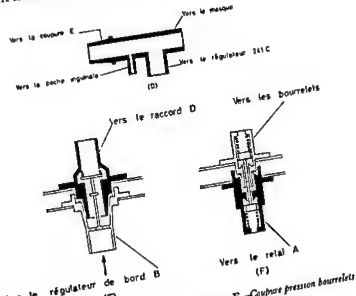

Fig 5 D—*Raccord 4 voies*, E—*Coupure basse pression*, F—*Coupure pression bourrelets*

Fonctionnement

(I) La pression cabine est supérieure à 151 mm Hg (correspondant à l'altitude 11,700 m).

Le vol est normal—La valve automatique du relais est ouverte. Les bourrelets sont en communication avec la cabine. Il n'y a pas de surpression. Le pilote

est alimenté par le régulateur de Bord Vergne 218. Le robinet du régulateur de secours Vergne 241 est fermé.

(II) La pression cabine devient inférieure à 151 mm Hg.

Vol avec surpression—premier cas. La valve automatique du relai s'est fermée à 151 mm Hg. Le détendeur altimétrique se met en marche, la pression monte dans les bourrelets à une valeur correspondant à la pression cabine et agit sur la membrane respiratoire des régulateurs 218 et 241. Ce dernier ne débite pas, le robinet de bouteille étant toujours fermé. Par contre, le 218 débite en régime surpression.

deuxième cas. Le régulateur 218 ne fonctionne plus. Le pilote actionne la commande manuelle d'ouverture du régulateur 241 et ferme le robinet d'arrivée d'oxygène du régulateur 218. Le relai pneumatique continue à débiter sous pression dans les bourrelets et cette pression réagit sur la membrane respiratoire du régulateur 241. Le clapet anti-retour de la coupure "E" se ferme et le pilote est alimenté en régime surpression par le régulateur 241.

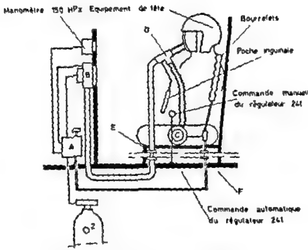

Fig 6 Schéma d'installation. Pour une installation il faut :

1 *manomètre* 150 *HPz*
A—1 *relais pneumatique Vergne* 218
B—1 *régulateur Vergne* 218.
C—1 *régulateur Vergne* 421
D—*raccord 4 voies.*
E—1 *coupure passage* 18 *à self obturation*
F—1 *Compure passage* 8 *à self obturation.*
1 *équipement de tête,* 1 *équipement de corps*

Ejection

Le pilote est obligé d'abandonner l'avion Au moment de l'éjection, le siège se libère de son support Le cable d'ouverture du régulateur 241 qui est fixé au support agit sur la poulie du robinet et le régulateur de secours

se met en marche Les deux coupures "E" et "F" se séparent, les clapets anti-retour ferment si l'éjection se fait au-dessus de 11,700 m, les bourrelets sont sous pression et le régulateur 241 débite en régime surpression. Au cours de la descenteen parachute, les bourrelets se vidangent par une fuite prévue à cet effet sur le régulateur 241, leur pression diminue et leur action sur la combinaison et sur le régulateur diminue également. Après un certain temps qui est fonction de la vitesse de chute, les bourrelets se trouvent à la pression ambiante et le régime surpression disparait. Le pilote est alors alimenté à la demande en oxygène pur.

Le montage des régulateurs peut se faire différemment (*Fig.* 7). Dans ce cas, aprés l'éjection, le relais barométrique 218 modifié reste sur le siège éjectable et assure la régulation du vêtement pressurisé au cours de la descente

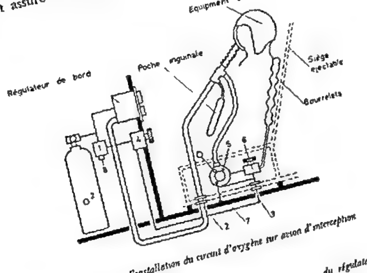

Fig 7 *Projet d'installation du circuit d'oxygène sur avion d'interception*

1. *Détendeur*
2. *Coupure à self obturation de 18*
3. *Coupure à self obturation de 4*
4. *Robinet altimètrique ou a commande mannuelle pour alimentation du régulateur de secours Vergne 241*
5. *Régulateur de secours Vergne 241 modifié*
6. *Relais altimètrique 218 modifié avec commande manuelle pour test au sol*
7. *Ouverture automatique de la bouteille de secours pour alimentation du régulateur 241 en cas d'éjection.*
8. *Prise auxiliaire d'alimentation*

Performances Obtenues Avec le Vêtement Pressurisé Français

Il ne nous a pas été possible d'expérimenter le vêtement pressurisé français jusqu'au maximum de ses possibilités, le casson dont dispose actuellement le Laboratoire de Biologie Aéronautique ne pouvant dépasser 20 à 21,000 m. Il est cependant intéressant de noter que les expériences menées à ces altitudes montrent que l'on peut y séjourner dans de très bonnes conditions de 10 à 20 min, suivant les sujets. A des altitudes plus basses, les temps de tolérance deviennent évidemment de plus en plus longs.

L'expérience a également montré que même à 20,000 m le pilotage d'un avion demeurait possible, ainsi que les manoeuvres d'éjection avec un siège à commande basse. Jusqu'à ces derniers temps, la manoeuvre du rideau de mise à feu d'un siège à commande haute était pratiquement impossible avec la pressurisation des bras; nous obtiendrons cependant, très prochainement, grâce à des artifices de construction du vêtement, une mobilité quasi totale des membres supérieurs, faisant ainsi tomber l'une des objections importantes que soulevait l'utilisation du vêtement pressurisé sur certains types d'avions.

Summary

Inasmuch as several prototypes of French aircraft can fly above 45,000 ft, we are encountering the problem of protecting crews against the considerable lowering of atmospheric pressure at the altitudes which are being reached.

All physiological studies made to date have shown that the best solution is to apply counter-pressure over the entire body. This is being accomplished by using the pressure suit.

The work of the Aeromedical Training and Research Centre has resulted in the development of a pressure suit which was tested in the low-pressure chamber at 60,000 ft. with very good results.

This French pressure suit consists of three principal components

I. Body equipment (pressurized garment)

II. Head gear (pressurized helmet)

III. Pneumatic equipment (regulators)

Body equipment

The pressurized garment, made of a nylon-cotton mixture, looks like a very tight-fitting suit. Mechanical counter-pressure is produced by inflation of rubberized tubes attached to the garment and located along specific lines. When inflated, they tighten the entire suit.

The suit is worn on top of a silk undergarment and is covered with an insulated flying suit.

Head gear

The pressurized helmet is composed mainly of a metal frame covered by a nylon shell and, in front, by a large plastic face piece. This in turn accommodates the oxygen connexion, inhalation and exhalation valves. On the side, there is a microphone and listening device. The entire helmet is covered with an anti-buffeting layer

Pneumatic equipment

This serves to maintain identical pressures on the body and inside the helmet. It consists mainly of an instrument panel control and an emergency control. They are synchronized by a pneumatic coupling

In the case of ejection, the emergency control becomes operative automatically

The tubes are deflated progressively during the descent. Experience in the chamber shows that at an equivalent altitude of 60,000 ft a pilot could continue to fly the airplane or eject himself with a seat having its actuating mechanism below elbow level.

It is expected that current research work will soon permit almost unrestricted mobility of the arms.

Fig 3 Flight clothing

1 MD-3 liner. 2. G-suit lead 3 Oxygen pressure hose leads 4 MA-2 vent suit lead

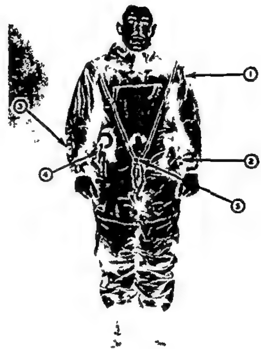

Fig 4 Flight clothing

1. MD-1 Anti-exposure suit. 2 G-suit lead 3 Vent-MD-1 Anti-exposure suit, 4. Oxygen pressure hose leads. 5. Vent suit lead

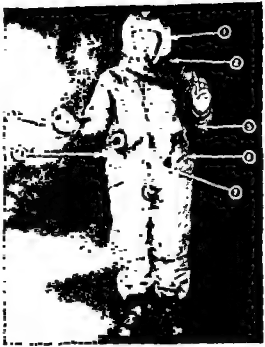

Fig 5 Flight clothing.

1 MB-5 Helmet 2 Helmet tie-down 3 Helmet face piece heater lead 4 Oxygen pressure hose lead 5 Vent-MD-1 Anti-exposure suit 6 G-suit lead 7 Vent suit lead

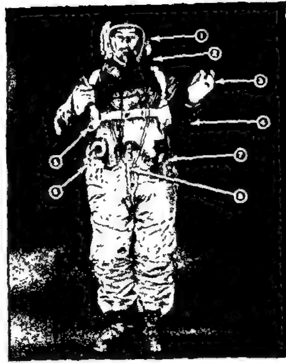

Fig 6. Flight clothing

1 MB-5 Helmet 2 Helmet tie-down 3 Face piece heater 4 Vent-MD-1 Anti-exposure suit 5 MI-2 Underarm preservers 6 Oxygen pressure hose leads. 7 G-suit lead 8 Vent suit lead

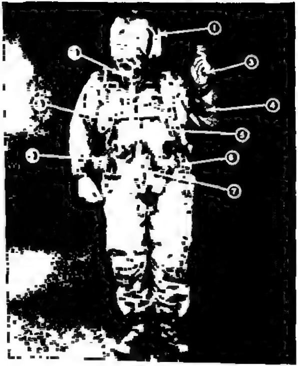

Fig. 7 Flight clothing

1. MB-5 Helmet 2. Helmet tie-down. 3. Face piece heater. 4. Vent MD-1 Anti-exposure suit 5 B-5 Parachute with automatic release 6 G-suit lead 7 Vent suit lead 8 MA-2 Underarm preservers 9. Oxygen pressure hose lead

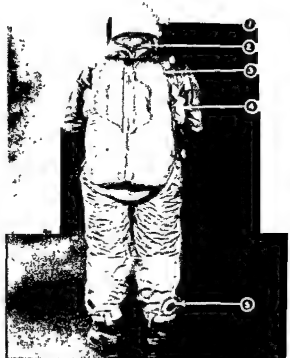

Fig. 8 Flight clothing.

1 MB-5 Helmet 2. Helmet tie-down 3 B-5 Parachute with automatic release 4 MA-2 Underarm preservers 5 Vent-MD-1 Anti-exposure suit

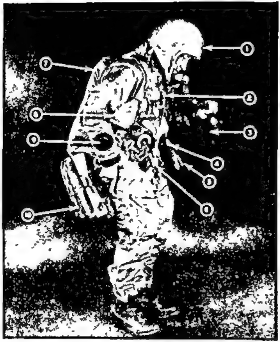

Fig 9 Flight clothing

1. MB-5 Helmet 2 Helmet tie-down 3 Face piece heater lead 4 Vent suit lead 5 G-suit lead 6 Oxygen pressure hose leads 7 B-5 Parachute 8 MA-2 Underarm preservers 9 Vent-MD-1 Anti-exposure suit 10. MD-1 Survival kit

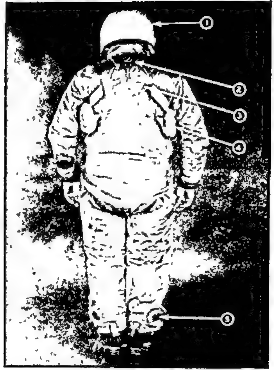

Fig 10 Flight clothing

1 MB-3 Helmet 2 Helmet tie-down 3 MC-1 Integrated harness 4 MA-2 Underarm preservers 5 Vent-MD-1 Anti-exposure suit

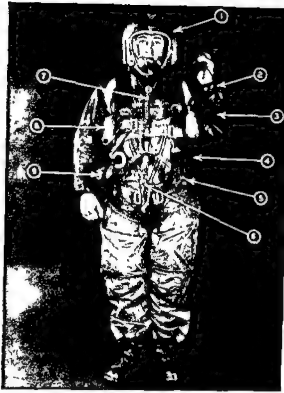

Fig 11 Flight clothing

1 MB-5 Helmet 2 Face piece heater lead 3 Vent-MD-1 Anti-exposure suit 4 XMG-1 Integrated harness 5 G-suit lead 6 Vent suit lead 7 Helmet tie-downs 8 MA-2 Underarm preservers 9 Oxygen pressure hose leads

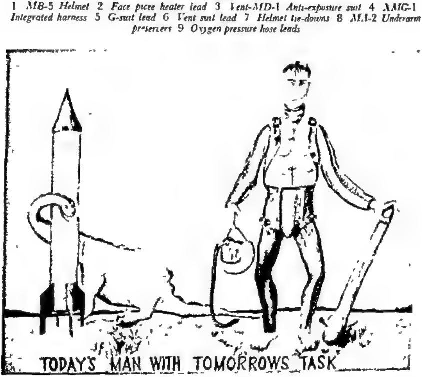

Fig 12 Today's man with tomorrow's task

Overwater and overland flights required the need for survival gear—A-1 kits for land and C-2A raft kits for sea.

Like the knight of old, we have continued to load the man to meet his enemy, however, unlike the knight of old, the increased weight of our armour is not to meet a tangible, living enemy, but to cope with nature, an enemy with many untold weapons.

As in past phases of armour development, we have again approached the upward climb of the curve or cycle which continues to repeat itself in the evolution of weapons. Like the knight of old, development of armour in the Air Force has gone through a period from maximum mobility to limited mobility. This point is especially true as a result of our present progress in the field of aircraft development. The capabilities of our present aircraft have forced us now to require more body armour in our battle with nature. The desire to conserve life and to reduce the chances of injury still persist in our attempt to cope with superior weapons. Flights to extreme altitudes require us to wear counter pressure suits and helmets against the rarified atmosphere. The ranges of aircraft have required us to wear what is now known as global armour—so as to protect us, in addition, to altitude, from e.g cold, water and to provide essentials for any terrain.

It is true that modern-day aircraft have facilities that may well reduce the number of items used—for aircraft have cabin pressure systems—air con- [illegible]

escape from his mobile, damaged armour.

The *Figs* show an airman dressing step for step in his personal protective armour for today's global flight.

Fig 1. An airman with his basic garment—the integrated G and partial pressure altitude suit. The leads on the right are capstans and the one on the left is "*g*" suit.

Fig 2 shows the airman wearing the ventilation suit to cool the man and keep him in thermal balance.

Fig. 3 now shows the man in a liner which provides the necessary clo value.

Fig 4 [illegible]

attempt to reduce weight, bulk, and complexity of the restraint and emergency harness attachment, the harness combines the function of shoulder harness, parachute harness, and lap belt into one garment. The Navy has already installed this assembly in several aircraft and the Air Force is now in the final stages of putting in into several aircraft.

Each of these items have been developed to do a specific job. We've spent considerable effort to combine or integrate the items so as to provide the

man with a minimum of bulk and yet provide him with a maximum of protection and comfort Even so, it is quite evident that we have limited his mobility, especially in a period where split-second action is of primary importance. However, if one considers each of the items, singly or collectively, one realizes they are essential and have often times served their purpose.

The arguments against body armour stem back from the beginning of time in spite of their value in numerous situations. If we examine the records of the sixteenth century, we are surprised how often armour saved its wearer. The fact is clear that, had cases not been numerous in which the soldier had been saved by his armour, the armour would not have been worn. Nor was the burden too great, considered from every viewpoint, if by means of armour a particular person could be saved. One has only to visit the royal armoury in Madrid today to know what such a man as Charles V thought of the practical value of armour. He was literally a specialist in its study and he provided himself with armour for every eventuality and of every weight which in spirit is not unlike the any or all need for the airman of today. He was a man of modest stature and proportion, yet his *tilting* armour for one particular effort weighs no less than 120 lb and his helmet alone over 40 lb. His protection was specialized for a particular situation. The airman shown to you in the figures is literally protected for any situation with a total equipment weight of 114 lb.

What I have presented to you today clearly brings out the point that, in the evolution of protective armour, which is continuous, there is a cycle. We have seen the pilot, who, during the infancy of aviation, started out with protective equipment that consisted of a bare minimum, initially the use of a parachute to a point in the present where he is essentially immobilized in an aircraft that has made tremendous advances and requires split-second timing and skill.

weight of the new compared to the present will remain essentially the same and the only item of equipment that will be eliminated is the exposure suit since the full pressure garment would serve both needs It is obvious that G protection, ventilation, clo value and so on is still required.

the chances of injury persist as a basic American philosophy and person...

...n is left to revert the man

...ngenious machine? Since

man, throughout time, has physically remained unchanged, we certainly cannot expect to impose continued hardship upon him if we are to maintain

Une série de 12 clichés montre le détail de ces différentes pièces d'équipement personnel, jusqu'au harnais "intégré" combinant en un seul ensemble le harnais d'épaules, le harnais de parachute et les sangles d'attache, réduisant ainsi poids et volume, mais au détriment de la mobilité. Le poids total est de 114 livres. La protection contre la "gifle" au moment du saut hors de l'avion nécessite une fixation très solide de tout l'équipement protecteur et réduit encore la mobilité.

On pourrait évidemment prendre certains risques, mais la politique américaine est de sauver le maximum de vies humaines.

Comme l'homme, par définition, ne peut être modifié, c'est l'avion qu'il faut modifier. Tous les éléments de protection devraient être réunis en un cockpit largable, seul le vêtement anti-g restant indispensable.

L'avion progresse toujours, la protection de l'homme réclame toujours du nouveau.

ESCAPE FROM AIRCRAFT

John P. Stapp

Chief, Aero Medical Field Laboratory, Holloman Air Development Center, Holloman Air Force Base, New Mexico, U S A.

Minimum requirements for escape from aircraft during inflight emergencies include:

(I) Effectiveness in accomplishing escape under all conditions of flight.

(II) Keeping the factors imposed by the escape process within limits of human tolerance

(III) Making the least demands on the operator by automatic sequencing of all steps in the process, including, in some situations, the initiation of the process (under extreme stress, human judgment and consciousness are more fallible than relays and timing devices)

(IV) The maintenance of, or emergency replacement of a viable environment during transition from aircraft to earth.

(V) Protection from ground or sea environment after landing.

(VI) Survival and communications equipment for use pending search and rescue.

The relation of conditions of flight to effectiveness of escape from aircraft in emergencies can be evaluated by reviewing U.S. Air Force experience with the ejection seat, consisting of less than a 1000 ejections since 1949, although the first U.S Air Force experimental ejection was in 1946.[7, 8] The ejection seat was a proven device in the German Air Force, with more than 60 reported combat ejections, before it was brought to the United States for study Intensive development, including numerous live ejections of human volunteers, occurred before it was deemed safe for standard use in jet aircraft. Research has never ceased on making it more fully automatic, increasing reliability of components and improving its range of effectiveness. The most important products of this research are the aneroid-timer for automatic parachute deployment, the automatic lap belt opener, and the downward ejection seat.

In *Figs.* 1 and 2, data[7] published by the Directorate of Flight Safety Research of the U.S. Air Force, has been converted to graphs showing per cent of survival, major and minor injury and fatalities with relation to altitude and speed respectively. The ejection seats in these cases had a definite altitude barrier of 1000 ft, below which only one out of four survive Add to this the numerous crash deaths and injuries where ejection was not attempted or was not even available, and the increase of low-level escape effectiveness becomes, in terms of numbers, one of our most urgent areas for research.

The British Martin-Baker[5] seat with successive cartridge firing and a 70 in stroke catapult has enabled escape from a Meteor jet on the runway

at 156 miles/hr by propelling the experimental volunteer upward 130 ft, with automatic stabilizing drogue chutes and main chute deploying in time to bring him down safely. A more generous margin of time and altitude for deployment and descent would be provided by as little as 10*G* of upward

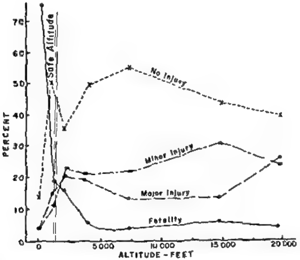

Fig. 1. *Indicated altitude relative to injury* 681 *ejections from operational experience with ejection escape systems, August* 1949 *to March* 1956

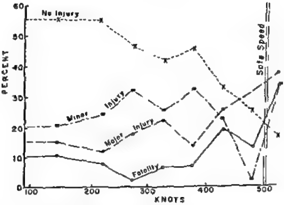

Fig. 2. *Indicated airspeed relative to injury* 665 *ejections, August* 1949 *to March* 1956

propulsion acting for half a second, elevating the man and seat about 450 ft above the point of ejection. The Martin-Baker seat has also been

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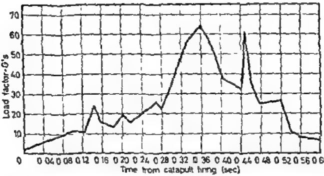

Fig 3. Probable acceleration-time history of George Smith case: ejection at Mach 1 05, 6500 ft altitude

Fig. 4) provided comparable measurements for reconstructing analogous trajectories for George Smith's ejection. These data are presented as the nearest to quantitative figures available on an actual ejection. It occurred at Mach 1·05 and 675 knots true airspeed, with a Q of 1280 lb/ft². The

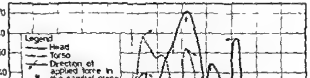

Fig 4 Resultant of vertical, horizontal and lateral accelerations, head and lower torso, 671 knots sled run

graphic data serves to indicate forces that could be survived with severe injuries to a man secured to the seat by a lap belt and comparatively loose shoulder straps. Measures to relieve negative G and reduce duration of congestion of head and face, and fixation of head, trunk and extremities might have done much to reduce severity and extent of injuries. The high decelerative and rotational forces are sufficient to account for these injuries

The first experimental measurements of these wind drag deceleration forces under conditions of flight were obtained in a series of four downward ejections of chimpanzee subjects in standard ejection seats from an air dropped missile accelerated downward to Mach 1·4 at 20,000 ft at the point of ejection. Analysis of the first two of these experiments is complete and is reported by the Cook Electric Company, contractors for the research. *Fig.* 5 shows a graph of resultant forces at the center of gravity of chimpanzee and seat. Because of mechanical failures in the recovery system, freefall of seat and occupant to the ground produced damage which overshadowed any evidence of injury during escape except in the third of these tests, not yet reported, in which the seat failed in a manner that caused strangulation of the anesthetized subject by a chin strap of the cloth muzzle, and no other lethal injury. This subject was parachuted down following the estimated opening shock of 35 G. The first two tests were instrumented; vital signs of heart beat and respiration persisted after ejection and during descent.

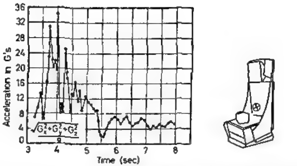

Fig. 5. Composite acceleration of the seat center of gravity vs time from Jato ignition, Cherokee Missile ejection of chimpanzee in seat, Mach 1·5 at 20,000 ft. Jato ignition t = 30 05 after release seat ejection occurs at approximately 4 25 sec.

[illegible] from [illegible] of separation. [illegible] and abruptly [illegible] gnitude of the imposed wind drag deceleration does not express the individual and combined effects of its component factors

Experiments to determine human tolerance to decelerative force[9, 10, 11] required controlled application of force with respect to direction, rate of onset and duration, in addition to the magnitude. This experimental programme has been in progress since 1947. The first objective was to determine the effects of abrupt forces encountered in aircraft crashes. Since 1953, the main effort has been to explore tolerance to deceleration patterns produced by wind ram during supersonic escape. Human volunteers were exposed to controlled increments of force in which factors were varied one at a time with the other variables held at tolerable values. Curves for a

typical experiment are shown in *Figs.* 6a and 6b. *Figure* 7 shows three curves which respectively indicate maxima for each of the three factors other than direction of force, which was transverse to the seated subject from front to

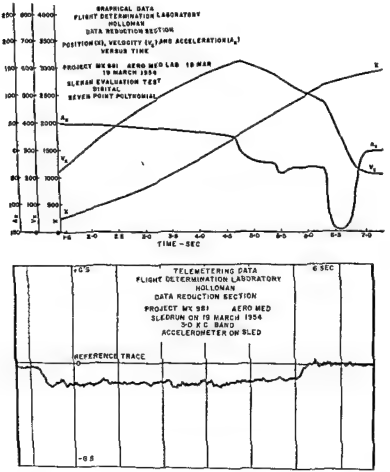

Fig 6 *Sled deceleration chimpanzees seated facing forward, Holloman Track,* 19 *March* 1954.
a Velocities and deceleration differentiated from time-displacement data (SLERAN)
b Accelerometer recordings telemetered from sled

back. Accurate presentation of experimental findings requires all three curves. In the transverse axis, any combination of rate of onset, magnitude

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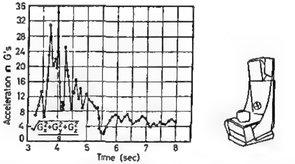

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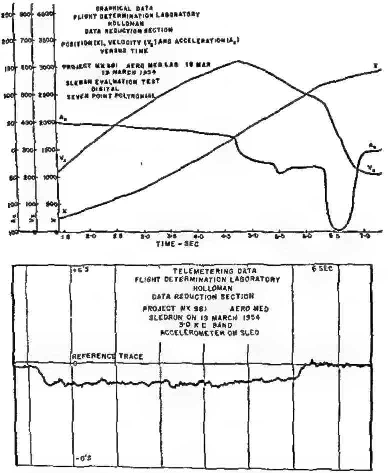

Fig 6 *Sled deceleration chimpanzee seated facing forward, Holloman Track, 19 March* 1954.
a Velocities and deceleration differentiated from time-displacement data (SLERAN).
b Accelerometer recordings telemetered from sled

back. Accurate presentation of experimental findings requires all three curves. In the transverse axis, any combination of rate of onset, magnitude and duration can be tolerated which does not exceed the experimentally established boundaries presented by these three curves. In the vertical axis, the limits of tolerance vary with the alignment and position of the vertebral column With the column in the erect position and maximum area at

The first experimental measurements of these wind drag deceleration forces under conditions of flight were obtained in a series of four downward ejections of chimpanzee subjects in standard ejection seats from an air dropped missile accelerated downward to Mach 1·4 at 20,000 ft at the point of ejection. Analysis of the first two of these experiments is complete and is reported by the Cook Electric Company, contractors for the research. *Fig.* 5 shows a graph of resultant forces at the center of gravity of chimpanzee and seat. Because of mechanical failures in the recovery system, freefall of seat and occupant to the ground produced damage which overshadowed any evidence of injury during escape except in the third of these tests, not yet reported, in which the seat failed in a manner that caused strangulation of the anesthetized subject by a chin strap of the cloth muzzle, and no other lethal injury. This subject was parachuted down following the estimated opening shock of 35 G. The first two tests were instrumented; vital signs of heart beat and respiration persisted after ejection and during descent.

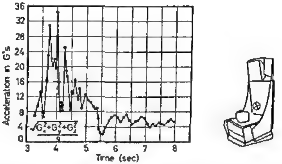

Fig. 5. Composite acceleration of the seat center of gravity vs. time from Jato ignition, Cherokee Missile ejection of chimpanzee in seat, Mach 1 5 at 20,000 ft Jato ignition t = 30 05 after release seat ejection occurs at approximately 4 25 sec.

... ejection and separation from ... at the instant of separation. ... nd abruptly ... itude of the imposed wind drag deceleration does not express the individual and combined effects of its component factors.

Experiments to determine human tolerance to decelerative force[9, 10, 11] required controlled application of force with respect to direction, rate of onset and duration, in addition to the magnitude. This experimental programme has been in progress since 1947. The first objective was to determine the effects of abrupt forces encountered in aircraft crashes. Since 1953, the main effort has been to explore tolerance to deceleration patterns produced by wind ram during supersonic escape. Human volunteers were exposed to controlled increments of force in which factors were varied one at a time with the other variables held at tolerable values. Curves for a

Fig 9 Human subject on Wright Field spin table during 120 rev/min, 5 sec *experiment Axis of rotation through heart*

apposition impinging between vertebrae, forces exceeding 30 G at 500 G/sec have been sustained without injury.

If the body is bowed forward to the limit of curving the spine, wedge fractures have been produced by 9–14 G at less than 500 G/sec in the first and second lumbar vertebrae. They were tilted forward until only the front rims of the vertebral bodies carried the concentrated loading.

Hydraulic forces can rise to the point of failure in blood vessels if a latent period of 0·2 sec required to overcome elasticity of tissues and viscosity of body fluids is exceeded.

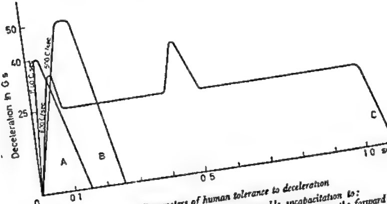

Fig. 7. Parameters of human tolerance to deceleration

Human tolerance to linear deceleration limit for reversible incapacitation to: A. Rate of onset B. Magnitude. C. Duration of decelerative force in the forward seat position

Another latent period of 3 sec or more is required for acceleratio long axis from head to foot to offset the pumping force of the deprive the brain of oxygen for long enough to affect vision and ness.

A composite diagram of the three orders of effects of mecha is shown in *Fig.* 8.

Tumbling in the head over heels direction has been investigat of human tolerance and lethal effect on animals by WEISS *et al* were spun on a turntable while lying on one side. (See *Fig.* 9.) W at the axis of rotation, humans lost consciousness in 12 sec at and results were fatal for anesthetized animals at 200 rev/min SPERRY *et al.*[9] in free fall bail-out experiments with the highest found disorientation, vertigo, nausea and loss of consciousne effects encountered. The less dense atmosphere at the greate mitted faster tumbling. In the same experiments, the im windblast at ram pressures higher than 650 lb/ft² at the inst caused flailing of the inadequately secured arms of the subje all muscular efforts to resist. In two cases, fractures and sulted at less than 500 knots and 30,000 ft.

Borrower's No	Due Date	Borrower's No	Due Date

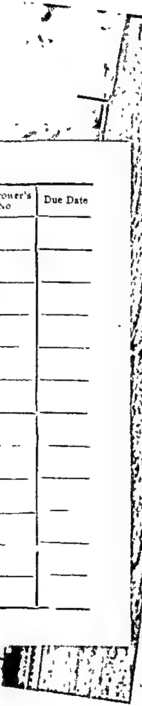

Fig 11 Windblast experiment Holloman Track, August 1955 Canopy being jettisoned in 50 msec for exposure to windblast at maximum sled speed Wind pressure 1800 lb/ft²

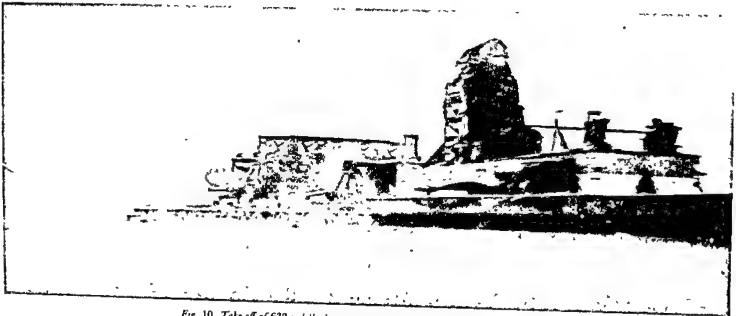

Fig 10. Take-off of 632 mile/hr human experiment, Holloman Track, 10 Dec. 1954.

No ill effects related to windblast occurred in a rocket sled experiment[11] in which the human occupant with head inclosed in windproof helmet and head and extremities secured against flailing was exposed to 1106 lb/ft² of windblast maximums during a 6·4 sec exposure. (See Fig. 10.) Rocket sled exposures to windblast in excess of 1800 lb/ft² have been sustained by similarly protected chimpanzee subjects without injury. (See Fig. 11.)

To control the conditions of escape in order to keep the factors imposed by the escape process within limits of human tolerance requires the following steps

(I) Stabilize the ejection vehicle to avoid tumbling. Tumbling has no proven benefit and it can be eliminated.

(II) Avoid known injurious effects of direct windblast resulting from flailing of head and extremities, fluttering of facial structures, and inflation of stomach with wind blown into facial openings, by securing arms, legs and head to escape vehicle and by encasing the head in a windproof container.

(III) Since there is no currently known way of excluding accelerations by an antigravity compartment, protection from the hydraulic effects of prolonged accelerations will require a counter pressure on the body to raise the threshold for blackout above redlines for aircraft manoeuvres. Regardless of the nature of the escape seat or capsule, its reaction to wind-drag must be regulated by some means to keep the deceleration following separation from aircraft within experimentally determined tolerable limits.

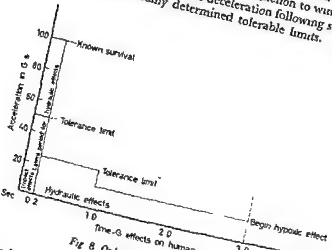

Fig 8. Orders of reaction to deceleration

This can be done by prolonging the duration and reducing rate of onset and magnitude of the deceleration. To achieve this may require increase in momentum of the escape vehicle by ballasting, or reduction in effective drag area, or addition of propulsion at right angles to deceleration to produce a tolerable resultant.

Numerous test pilots have expressed a wish that a single push button could be provided to actuate an escape system quickly and dependably, so

that decision to abandon an expensive prototype could be delayed until clearly inevitable. The two leading causes of fatality following ejection have been failure manually to separate from the seat and manually deploy the parachute. The introduction of the automatic lap belt cartridge and aneroid-timer parachute deployment sequence, and the successful functioning of these devices in the one low altitude supersonic escape to date indicate a successful solution to this problem.

It has been long accepted that flight above 10,000 ft requires supple-

atmospheric pressure is breathed; and that loss of pressure to the equivalent of 63,000 ft ambient decompresses body fluids to their boiling point at body temperature; and that environmental temperatures below freezing can frost bite exposed skin when airflow is rapid; and that positive accelerations can produce greyout and blackout in accordance with well known experimental curves of time versus G.

No one disputes that an excess of cumbersome gear slows down scrambles, causes fatigue, hampers movement in the cockpit and reduces safety of operation. The problem of eliminating, integrating or comfortizing personal equipment without compromising safety is not easy.

Parachutes can be taken off the pilot's body and attached to a seat or capsule. The crash function of restraints can be made secondary to escape positioning of the body, if ground level to 1000 ft capability can be built into the escape vehicle. If a minimum partial pressure suit is acceptable for quick descent below 50,000 ft prior to escape, in case of cabin pressure loss, to continue descent and land, the full pressure suit can be eliminated.

... is the primary
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SOMMAIRE

L'auteur présente, à l'aide de 11 *diagrammes, les principales données relatives à l'évacuation du bord par siège éjectable dans l'U.S. Air Force.*

... total de

... heures,

Fig. 2. *Mêmes indications, en fonction de la* vitesse *de vol.*

Fig. 3. *Accélération probable au niveau de la tête au cours de l'éjection En abscisse, le temps en secondes à partir de la mise à feu de la cartouche. En ordonnée le facteur de charge en G.*

Fig. 4. *Résultantes des accélérations verticales, horizontales et latérales au niveau de la tête et de la partie inférieure du thorax, à la vitesse de* 671 *noeuds*

Fig. 5. *Accélération composée au centre de gravité du siège par rapport au temps en secondes depuis l'allumage de la fusée auxiliaire de décollage.*

Fig 6 a et b. Courbes caractéristiques d'accélération et de décélération du traîneau à fusées (Laboratoire d'Holloman) en fonction du temps.

Fig. 7. Limite de la tolérance humaine à la décélération linéaire, en fonction de la vitesse d'installation, de la grandeur et de la durée de la force de décélération en position assise face en avant.

Fig. 8. Effets de l'accélération sur le corps humain en fonction du temps.

Fig. 9. Sujet humain sur la table vrillante de WRIGHT FIELD *au cours d'une expérience de 5 secondes à 120 tours-minute Axe de rotation passant par le coeur.*

Fig 10. Départ d'une expérience sur l'homme à 632 mile/hr. (Holloman, 10 Dec. 1954).

Fig. 11. Experience d'Holloman, Août 1955. Le canopy est largué en 50 msec pour obtenir l'exposition au choc aérien (wind blast) à la vitesse maxima du traîneau. Pression de l'air: 1800 lb/ft².

REFERENCES

1 GOODRICH, J. W. "Escape from high performance aircraft". USAF Aero Med. Lab. Tech. Note 56–7, 1956.

2 HEGENWALD, J. F, JR. and BLOCKLEY, W. V. "Survivable supersonic ejection, a case study to correlate analytical, experimental, and medical data by reconstruction of an incident, an interim report". North American Aviation, Inc , Report No. NA 56·452, 1956

3 JONES, W. L. "A study of bailouts for a five year period in the U.S. Navy". *J. Aviat. Med* 22, 123, 1951.

4 LOMBARD, C. F., AMES, S. W., ROTH, H. P. and ROSENFELD, S. "Voluntary tolerance of the human to impact accelerations of the head". *J. Aviat. Med.* 21, 1091, 1951.

5 MARTIN, J Personal communication

6 MAZZA, V. "High altitude bailouts". *J. Aviat. Med* 21, 403, 1951.

7 MOSELEY, H. G "Operational Experience with Ejection seat systems". Directorate of Flight Safety Research, USAF, 9 April 1956.

8 ROTHWELL, W. S. and SPERRY, E. G. "Escape from aircraft by downward ejection". *J. Aviat. Med.* 24, 322, 1953

9 SPERRY, E. G , NIELSON, H. P. and BARASH, I. M. "Downward ejection at high speeds and high altitudes" *J. Aviat. Med* 26, 356, 1955.

10 STAPP, J. P. "Human exposures to linear deceleration 1. Preliminary survey of the aft-facing seated position". U S.A F. Aero Med Lab., Tech Rpt 5915, 1949; 2 "The forward facing position and the development of a crash harness", USAF Aero Med Lab., Tech. Report 5915, 1951.

11 STAPP, J. P. "Effects of mechanical force on living tissues. I. Abrupt deceleration and windblast". *J. Aviat. Med.* 26, 268, 1955.

12 STAPP, J. P. and HUGHES, C. D. "Effects of mechanical force on living tissues II. Supersonic deceleration and windblast". *J Aviat. Med.* 27, 407, 1956.

13 WEISS, H S., EDELBERG, R. CHARLAND, P. V. and ROSENBAUM, J. I. "Animal and human reactions to rapid tumbling". *J. Aviat. Med.* 25, 5, 1954.

U.S. NAVAL AIRCRAFT INSTRUMENTATION PROGRAMME

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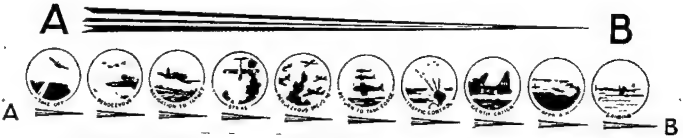
From a paper delivered at the AGARD meetings two years ago you learned that the Navy is engaged in a comprehensive programme for the improvement of instrumentation, of which the long-range aspect is the responsibility of the Office of Naval Research. This paper is an outline of the programme with a review of the methodology employed, the conduct of the programme and the results to date.

Since one of the primary missions of the Office of Naval Research is to look ten to twenty years into the future, our requirements were based on concepts of aircraft of the future. After making an analysis of these requirements, it became evident that present instrument displays would not be adequate and it was decided to take a fresh look at instrument design, the [illegible] statement of the problem. [illegible] . *Overall flight* [illegible] avigation, strike or mission, rejoin, return, traffic control, identification and landing. Results of these studies indicated that in carrying out the various phases of flight, information can be obtained from five sources: the air, the aircraft, the earth, the pilot and other aircraft. It was further established that there are four basic discriminations which must be made by the pilot, which are: direction, altitude, time and mechanical (or control). The analysis also indicated that if the data presented to the pilot is to be adequate it must answer five questions, which are, which control to move, when to move it, which direction, how much to move it and how long to hold it. In summary, then, our problem was fairly well defined. In order to design instrument displays adequate for flying aircraft, they had to be capable of answering each of the five questions, for each discrimination, for each phase of flight.

The tremendous rate of aircraft development has forced instrument engineers to take care of so many "fire drills" that they have never really had the time to develop ways for eliminating the cause of the fires. In almost every instance, new instrument development has been carried out on a crash programme brought about by the necessity for more data, and caused by technological advances in aircraft performance and capability.

It was apparent that this constant necessity for "fire drills" would continue to force us to accept compromises unless we established a separate programme of fire prevention. In other words, a long-range research programme had to be carried on simultaneously with the everyday programme and conducted in such a way that only fundamentals were considered, and with the thinking completely uninhibited.



SOURCES OF INFORMATION

The earth
The air
The aircraft
The pilot
Other aircraft

DISCRIMINATIONS

Direction
Altitude
Time
Mechanical

INFORMATION REQUIRED

(I) Which controls to move
(II) When to move them
(III) Which direction to move them
(IV) How much to move them
(V) How long to move them

Fig 1 Flight job analysis

In order to clarify our terminology, an explanation of "uninhibited thinking" is in order. In this instance, such a mental process can be described as an attempt to analyze a problem down to its bare fundamentals, without prejudice, bias or opinion; without seeking an immediate solution or compromise, in order to define the problem as completely and clearly as

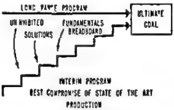


Fig. 2. Dual programme.

possible. To accomplish this one must divorce this thinking from his limited pool of knowledge of existing partial solutions to the problem, and assume that no solution exists in any form One can approach the fundamentals by continuing to ask either *why* or *what for* until no further questions can be asked.

In order to conduct a successful long-range programme, it is essential that the effort be carried out by a team rather than any particular group of engineers. In order to achieve good instrument design, we must eliminate,

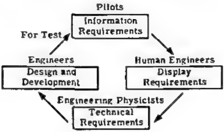


Fig. 3. Instrument team.

as far as possible, personal opinion. Because a pilot has flown several thousand hours, or an engineer has worked on instrument development for ten years, does not in itself make either of them qualified to determine the *type of indication* needed on the instrument panel. The pilot can very definitely tell us what he needs in the way of information, but he can only compare one display with another when asked how to indicate the information. The engineer on the other hand can tell us whether or not it is possible and practical to make one display or another, but is not really qualified to objectively determine the proper method of indicating the display. This is not meant to belittle either of these men, but rather to point out that each has a particular part to play in a coordinated programme. The only practical

way to make the best use of individuals with particular skills is to have them work as a team, each covering his particular field of endeavour.

Such a team requires pilots to establish information requirements; human engineers to use these requirements as a guide in order to establish display requirements; a feasibility group of engineers and physicists to establish technical requirements for the display; engineers to actually design and develop the equipment; and last but not least, flight surgeons to define the parameters of pilots' performance capabilities and keep us constantly reminded that a man is the indispensable link in this sytem.

In the short span of 35 years the airplane has advanced from the relatively simple propeller driven machine of World War I to the jet propelled supersonic aircraft of today.

Man on the other hand, over a period of 3,000,000 years has changed very little—nor will he change very much in the next 3,000,000 years.

With due consideration for all other parameters, man's psycho-physiological limitation is the constant around which any man-machine system must be designed.

ORIENTATION—What am I doing?
DIRECTOR—What should I be doing?
QUANTITATIVE—How am I doing?

Fig. 6. Types of Instruments.

Fundamentally the instrument problem involves much more than just the design and development of a group of instruments for installation in a cockpit. The problem in fact is primarily one of creating a man-machine [illegible] of both factors. The machine we [illegible] at, [illegible]

Of all the sensory systems, vision is the strongest especially in effecting [illegible] in the man-machine problem [illegible] ompatible with the [illegible]

In order to bring about a proper display it is necessary to sense certain phenomena. This data must be computed in order to produce the display.

In order for the man to respond to the display a control system must be furnished. In addition, there must be a means of communication both internally and through radiation.

The overall problem, and this incidentally applies to almost every type of research and development, falls into five areas: (I) Display, (II) Sensing, (III) Computation, (IV) Control and (V) Communication. The man's requirements are the starting criteria.

In the case of display for aircraft, the primary question to be answered is simply, "What is it the pilot needs to have displayed?"

There are actually two major requirements. These are, position in space; and geographical position. The first is observed normally with respect to a vertical plane and the second with respect to a horizontal plane. The first is primarily orientation, the second situation display.

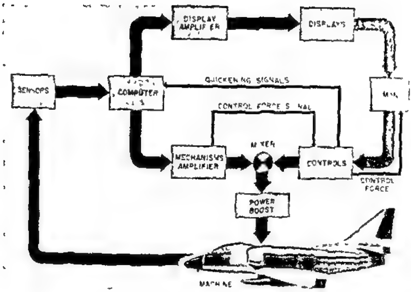


Fig 4

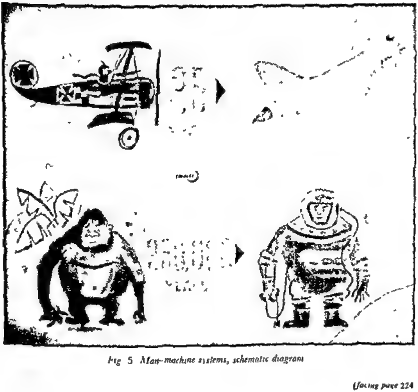


Fig 5 Man–machine systems, schematic diagram

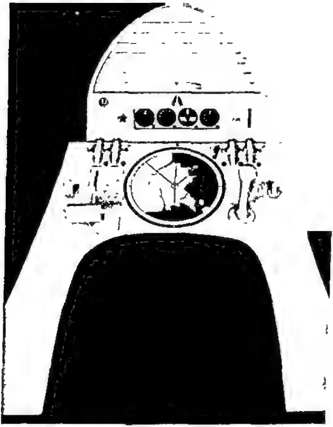


Fig 7

Each of the two areas must be further divided into three types of display.

I. Orientation, which tells the man what he is doing.
II. Director, which tells the man what he should be doing.
III. Quantitative, which tells the man how he is doing.

In order to determine the details of these three types of display it was necessary to make a complete analysis of the Information Requirements. To determine these requirements pilots were interrogated to establish the fundamental information necessary to accomplish the task at hand. Not as interrogation of the individuals opinion but rather an assessment of the essential information required with which the task could be accomplished without interpolation or mental computation. For example, during an air interception the pilot must have range information. The fire control engineers, realizing this, provided a means for determining range and then proceeded to present this information in the terms in which they had always defined range—in miles and yards However, when pilots are asked the question, "Why do you want range information?", they answer by stating that they need range data in order to know *when* to lock on, *when* to fire, and *when* to break. *When* denotes time, not distance. In other words, fundamentally, range must be indicated as a director type of presentation in order to eliminate the necessity of the pilot remembering at which range to lock-on fire and breakaway. When the questioning reaches a point where the operator states that without X data he cannot carry out the task, then X data is the fundamental information requirement.

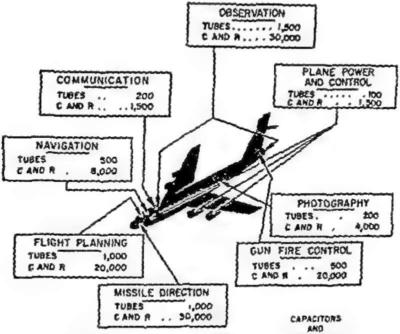
These information requirements had to be established for each phase of the task from beginning to end.

Having established these fundamental requirements the next task was to select a yardstick which was adequate in order to determine the display requirements. In most instances this yardstick is merely that which is most natural. In the specific case of orientation, the visual world is the yardstick because with some exceptions pilots do a fairly good job of flying when they have access to the visual world. This is due to the fact that our behaviour [illegible]

the various phases of flight.

If we resort to invention we can only compare an idea with another, both of which may be fundamentally wrong. On the other hand, if we use the visual world as one of the elements of our comparison, which we know incidentally is adequate, we at least can establish an equally adequate display. This comparison then is made against a natural, rather than a man-made model. If we can create a synthetic display comparable, (not a duplicate) to the visual world, then we known axiomatically that the display will be adequate. Having once established this we can then proceed to [illegible]

the display for which we must create a correlate. The proof here for display is by axiom rather than evaluation because if it is true that we orient ourselves by our perception of the visual world, it follows that our display must be adequate if it reproduces the same cues which are apparent in the visual world.



CLASS	TUBES	CAPACITORS AND RESISTORS
FIGHTER	600	9,000
PATROL BOMBER	1,200	20,000
RADAR OBSERVATION	3,000	80,000
HEAVY BOMBER	5,000	119,000

Fig. 8.

The actual display is presently being integrated by our human engineers. The results to date are not complete enough to exhibit the final display. The following however will describe it in general terms.

The concept consists of two basic displays; one in the vertical plane giving orientation information, and one in the horizontal plane providing position or a situation display.

The data displayed on the vertical unit includes attitude information, altitude and velocity indications, obstacles and weather information, and director type of information. The configuration of the display is integrated in such a way that direct answers are provided to the pilot rather than a series of factors which require mental interpretation. Attitude includes more of a representation of the visual world than just a horizon line. Altitude is represented by horizontal lines indicating levels rather than a clock type

indication as the standard altimeter. Velocity is relative rather than numerical.

established requirements.

Engine information is provided by a series of indications on both vertical and horizontal displays. Such indications include "how goes it" information as well as emergency data.

Functional switches are provided to select data to be displayed on both indicators as desired by the pilot of each mode of flight. This eliminates all information from the displays except that required at the particular phase of flight.

In summary, the displays are a representation of the elements apparent in the visual world rather than a pure contact display. They are presented to the pilot in such a way as to eliminate the necessity for reconditioning his reflexes. Training required will be a minimum because in effect there is little or no transition from contact to instrument flight.

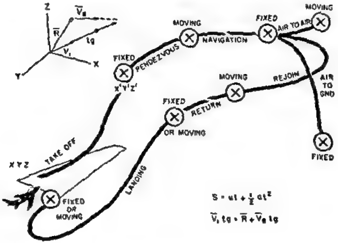


Fig 9.

Sensing certain phenomena is essential to producing any display. In the past, we have chosen to divide the problem into specific types of instruments such as flight instruments, navigation instruments, fire control, landing, engine, etc. As aircraft became more advanced, it became fashionable to include more than just the instrument and refer to the development as a "system". These systems each include sensors, amplifiers, computers, indicators, etc. and were developed for a specific type of aircraft. In stating

the overall problem, which includes all of the various flight modes, it appear that each mode is in reality only a repetition of the other, and if we solve one, with very few exceptions, we solve them all.

For example, the only real differences between landing and take-off is the application of power. The equations are the same. The only real difference between rendezvous and air interception is that in the latter case we release the armament. The only difference between take-off and rendezvous is the plane of operation. In the final analysis, all modes of flight are in fact only variations of navigation, and navigation is the summation of a series of orientations. The same fundamental equations apply for all modes. The media through which these displays are presented to the pilot consist of flat plate transparent television tubes now being developed as a part of this programme. Upon this tube the right kind of information can be displayed—when the pilot wants it, in a form he can use it, and without the complication of extraneous information which he does not require to enable him to do the job at hand—be it take-off rendezvous, strike or landing.

SUMMARY

It can be stated that considerable progress has been made in the instrume programme during the last two years In fact, five major "breakthrough have been achieved.

The first was in the application of a new technique or approach to th instrument problem which consists of seeking the fundamental rather tha a partial solution to the problem. This approach results in the following discoveries.

A new display for instrument flight which required an absolute minimum of training and provides information which produces little or no disorientation.

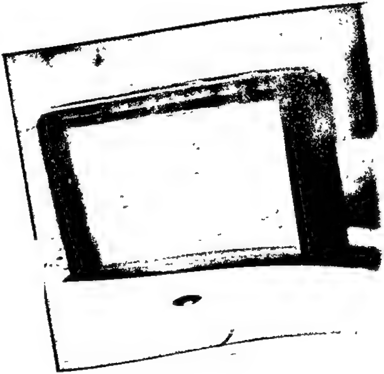
A medium for presenting the display consisting of a flat transparent cathode ray tube

A centralized light weight inexpensive universal computer capable c solving all computation required for all missions and modes of flight.

And the fifth "breakthrough", was the development of a new concept consisting of a design for a standard ejectable cockpit capable of being "plugged" into different wing-engine configurations for wide mission capability.

Governing this entire programme there is a philosophy which may be described as follows·

For every problem we face there may be only a few, or an infinite number of solutions, but out of this few or infinite number there is only one logical, completely adequate, and thoroughly compatible answer. All others are only partial solutions. When men distort or overlook the fundamentals, the result can only be a partial solution. Where the analysis is complete and the basic fundamentals are established, the results will be not only complete, but simple as well. We are looking for—and getting—those right answers.



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Déjà exposé il y a deux ans à AGARD, ce programme fait aujourd'hui l'objet d'une mise au point exposant les résultats obtenus. Il est délibérément orienté vers un avenir d'une vingtaine d'années; en raison des progrès très rapides de la technique aéronautique il ne peut s'agir que d'un programme à long terme, libéré des nécessités immédiates et des solutions partielles existantes. Il doit être exécuté par une équipe comprenant des pilotes, des ingénieurs, des physiciens et des médecins de l'Air. Si l'homme ne change pas, et compte-tenu des autres paramètres, les limitations psychophysiologiques de l'homme représentent la constante autour de laquelle doit être construit le système homme–machine.

Les données dont le pilote a besoin se groupent en deux rubriques majeures:

(I) la position dans l'espace, qui se situe par rapport à un plan vertical (orientation),

(II) la position géographique (situation), par rapport à un plan horizontal.

Chacune de ces deux rubriques doit être divisée en trois types de présentation·

—l'orientation, qui dit à l'homme ce qu'il est en train de faire;

—la direction, qui lui dit ce qu'il doit faire;

—la quantité, qui lui dit comment il le fait.

Un principe fondamental pour établir un tableau d'information est de faire "ce qui se fait naturellement". Dans la vie courante, c'est par la vision que nous nous orientons. Notre système sera donc adéquat s'il reproduit les mêmes données qui apparaissent dans le monde visuel.

Le dispositif réalisé par l'Aéro-Navale comprend donc

(I)—un tableau vertical *renseignant sur l'orientation, c'est-à-dire l'altitude de l'avion, son altitude et sa vitesse, les obstacles, la météo—toutes ces données étant intégrées de telle sorte que le pilote a une information directe et non une série de facteurs demandant une interprétation mentale;*

(II)—un tableau horizontal *renseignant sur la position géographique, la consommation d'essence et le cap.*

Les données concernant les moteurs figurent sur les tableaux horizontal et vertical. Des manettes permettent au pilote de sélectionner les renseignements nécessaires à une phase donnée du vol.

Tous ces éléments sont présentés au pilote de façon à lui éviter la nécessité de reconditionner ses réflexes, l'entraînement exigé sera minimum car il n'y a que peu ou pas de transition entre le vol au contact et le vol aux instruments.

En dernière analyse, les diverses modalités de vol ne sont que des variantes de navigation, et la navigation est la somme d'une série d'orientations. Les mêmes équations fondamentales s'appliquent à toutes les modalités. Elles sont présentées par l'intermédiaire de tubes de télévision à plaque transparente sur lesquelles le pilote peut choisir l'information dont il a besoin.

Tout cela constitue un progrès considérable, et l'adaptation du dispositif est déjà faite à un cockpit éjectable standard capable d'être incorporé à diverses structures d'avion.

FUTURE TRENDS IN PROTECTING AIRCREWS

D. Flickinger

Brig.-Gen. USAF., Headquarters ARDC, Baltimore, U.S.A.

To many of us who have been working in the Human Factors field the news of the 1000 knot speed capability of the USAF production F 104 has been [illegible] ,e, our feelings are [illegible] and perseverance [illegible] and planners who made possible this noteworthy accomplishment. Close akin to pride we also share a feeling of security with the rest of the nation, for in this era in which we now live, our ability to discourage a potential aggressor force is directly related to the qualitative superiority of our deterrent Air Force. Mixed in, however, with these understandably good feelings there comes to us again, and with increased urgency, the realization of the many problems which confront us in engineering our manned weapon systems for maximum operator performance and safety.

When we realize the many unsolved problems we now face in achieving the desired degree of safety and functional compatibility of the operator in aircraft of considerably less performance capability than the F 104, and further, if we wished to take a rather pessimistic view of the situation, we might expand the title of this paper in a succinct fashion by saying that the future trends in protecting aircrews will all be towards one objective, namely, to take them out of our combat aircraft and substitute unmanned weapon systems. To this view, however, I cannot ascribe, since I can never believe that American science and technology are incapable of solving any biophysical problem, given the necessary time and resources. More specifically, I would oppose that view on the grounds that the potential pay-off in finding the solution to these problems is far too great for both military and peacetime [illegible] interests and efforts in this field.

[illegible]

warrant their replacement of a segment, and I repeat, a segment only, of our total deterrent air power. Such missiles will become a most valuable adjunct to our manned weapon system, but I cannot foresee any time in the future when it would be feasible, practical or even expedient, to replace the human operator in all space-traversing vehicles whether they be committed to peaceful exploration of new frontiers or missions in the interest of national security and economy. Difficult though he may be to understand and measure in all his variance of mood and response, man, as a non-linear computor with judgment, motivation and loyalty can never be satisfactorily or economically replaced, and will continue to have infinite value and usability. If we are to continue to use him then in our military aircraft, both present and future, we must on the one hand insure complete compatibility

between the demands of the aircraft system–mission–environment configuration, and the operator's ability to meet them with enough deviation allowance to prevent failure and destruction from occurring as the inevitable result of any significant overloading, and on the other hand, we must assure him of reasonably acceptable odds for safe escape from the system once it is *irrevocably committed to disaster.*

It is to these two topics then that I address my brief discussion today. First, how can we make our crew recovery systems more effective and reliable, and second, how can we design and operate our manned aircraft in a manner which will require use of the escape system only in rare instances.

The Problem of Emergency Escape Systems

Despite the many outstanding contributions made toward defining human tolerances to deceleration, wind-blast and tumbling, plus the significant improvements in configuration and reliability of ejection seats, our record today does not encourage complacency. The disturbing and challenging facts of the situation are as follows·

(I) Analysis of all existing biophysical data indicates fairly conclusively that our present ejection seat escape system is inadequate for uniformly safe crew escape at speeds in excess of 600 knots indicated

(II) The performance capabilities of our present century series fighters places them in an operational speed range which would result in 26 per cent fatalities in all attempted escapes.

(III) No escape system to our knowledge has as yet been tested above 47,000 ft altitude.

(IV) The greatest number of fatalities resulting from the use of our present escape systems occur from attempts made below 2000 ft altitude.

(V) The continued application of devices, clothing and equipment to the crew member, in order to protect him from all possible environmental hazards, is seriously compromising the reliability and effectiveness of the present escape systems even when used within the acceptable limits of velocity and altitude.

Accepting these facts as they are, and realizing at the same time that the maximum available speed will be used in the combat situation, it is obvious that we must intensify our efforts towards both an immediate and long-range solution to the problem. Certainly from the standpoint of personnel and economy, let alone the morale factor, we cannot afford the loss of 25–30 per cent of our crew members who are forced to use the escape system.

Two different approaches are being made towards a satisfactory solution to the immediate problem; one attempts to alter the velocity envelope of the aircraft prior to ejection, and the other strives to modify the deceleration profile of the ejected mass to within biologically acceptable limits.

(I) The first approach consisting of drogueing the velocity of the aircraft down to a degree and within a short enough time interval to provide safe ejection has many advantages if proven to be workable and feasible. It could be applied to aircraft without modification of the existing cockpit and seat configuration, and the slight additional weight should do little to

balance, speed or range. In addition, it would have the advantage of requiring no change in the presently learned crew procedures for seat operation.

(II) The second approach aims at flattening out the deceleration curve of the ejected mass by increasing its total weight and density. There may be advantages to this approach which are not apparent to me, but I would personally think that it would be used only as a last resort after it was certain that the first could not be accomplished. Adding weight to the present seat, whether it be components or dead weight, would have the disadvantage of altering the weight, balance and range of the aircraft, and, in addition, requiring a complete change in the ballistics of the system with possible reduced reliability.

For the long-range solution, the prospects of a new system which would have a wide range of applicability to both aircraft types and speed-altitude environments seem somewhat brighter. The Navy, Air Force and aircraft industry are teaming their efforts in a well-coordinated and energetic fashion towards an early realization of this objective, and preliminary results are encouraging. They indicate that a protective shell can be built around the crew member within the main structure of the aircraft with very little cost in weight, which would, on the one hand, if ejected, behave in a completely acceptable manner to its occupant. In addition such a shell or module would offer many other advantages, such as:

(I) Provide complete protection from wind-blast, debris and temperature extremes.

(II) Provide a floatable container in the water or a habitable enclosure on land with ample storage space for survival equipment.

(III) Eliminate fairly completely the present requirement to have bulky and restrictive protective equipment hung on the crew member which adds little, if anything, to his comfort and efficiency.

The one flaw in this future solution, attractive as it appears, lies in th fact that it will not handle successfully the problem of emergency escap at low altitudes during the landing and take-off modes. However, I feel confident that an engineering solution to this dilemma will be found even if it be as radical a concept as removing all necessity for high speed, long runway landings and take-offs. It is conceivable to me, at least, that in the reasonably near future new methods of applying propulsive energy to aircraft will be found which may well remove essentially all the hazards from these modes, leaving them as the safest in the entire flight profile.

ENGINEERING FOR OPTIMAL SAFETY AND FUNCTION OF THE OPERATOR-MACHINE SYSTEM

Of all the challenges facing aero-medical, human factors and performanc engineering groups perhaps the most difficult and intriguing is the one evolving from our aircraft accident picture. How can we design and operate our manned weapon systems in a manner which will insure greater integrity and less requirement for the use of the emergency escape system? How can we analyze and solve the problem of operator-machine malfunction which leads to destruction of the total system?

The potential benefits to be gained by the Air Force from even a partial solution to this problem are enormous. The preservation of highly trained personnel and costly equipment, plus the increased morale and motivation of aircrew members, are all factors of major importance.

In its simplest form perhaps we can say that an aircraft accident occurs as the result of some major incompatibility which arises somewhere in the operator–machine–environment configuration. We have trained our operator in the best manner we are capable of, and we have given him a job to do with a machine which is built to the best possible standards for performance and safety. Yet, in too many cases, something happens despite the operator's best efforts to prevent it, and both he and his machine come to an untimely end The answer to your natural question of "in how many cases" can be at least partially gained from a review of the following accident statistics:

(I) Human error was credited with two-thirds of the major accidents [illegible]

(II) [illegible]

the 1950–55 period.

(III) Jet trainers and fighters account for 68 per cent of the major accidents and 66 per cent of the minor ones yielding a total of 73 per cent of the aircraft destroyed, yet fly only 29 per cent of the total hours flown.

(IV) Landings and take-offs account for 61 per cent of all accidents in jets and 66 per cent in non-jets.

From even a brief consideration of these figures, we can make a few simple and basic generalizations·

(I) The malfunction attributed to the operator component in our total configuration is the primary factor involved.

(II) When a major accident occurs, it is much more apt to be fatal than formerly.

(III) Landings and take-offs are the most hazardous portion of the job in any aircraft.

(IV) Jet aircraft with a single operator are much more difficult to keep out of trouble than all others combined.

Having made these generalizations, a number of interesting questions are presented to us

(I) What is the actual operator malfunction involved, what is the sequence or pattern of its occurrence, how can we reduce it?

(II) How do the two factors of increased speed and complexity of operation in our current high-performance aircraft balance out in accounting for the increased hazards involved in any major accident, in singly operated jets, and in the landing and take-off modes?

The two questions above are obviously interrelated, but I have separated them purposely since I wish to focus attention and consideration to the first, dealing with the so-called human error or operator malfunction. What is the actual malfunction involved; what brings it on, and how do we prevent it?

ACCIDENT ANALYSIS AND RECONSTRUCTION OF EVENTS

Realizing the great strides made in reconstructing material failures as prime accident factors, we look first to accident analyses for clues to our question of "what human error". Is it possible through reconstruction of events and post-mortem studies to determine·

(I) What was the "functional ready state" of the operator at the time the dynamic accident potential of his machine-environment built up to certainty.

(II) What was the sequence of demands placed upon him by the system and environment which eventually exceeded his capabilities for effective response.

Unfortunately, despite the commendable progress made by the Directorate of Flight Safety in accident investigation techniques, we are still greatly handicapped in our ability to analyze and reconstruct the human factor in the accident. Port-mortem studies are performed on only a very small percentage of fatalities, and even when done, do not yield all the objective data we require In some cases, reduced functional states due to anoxia or carbon monoxide toxicity can be identified, but the less dramatic reductions in the functional ready state evade detection.

We might, therefore, list the following objectives or trends as being worthy of consideration in attempting to reconstruct the operator malfunction factor in aircraft accidents:

(I) Improvement of techniques for pathologic study of toxicants, and altered physiologic states, plus much greater use of post-mortem examinations.

(II) Development of crash-proof instrumentation which would yield us more accurate data on the sequence of events as they built up to the inevitability of the accident.

(III) Greater emphasis and study on the problem of the functional ready state of the operator, particularly as it is related to fatigue, tobacco, alcohol, and a host of minor physical and psychological ailments.

(IV) More complete reporting of near accidents by aircrew personnel.

SYSTEM DESIGN FOR OPTIMAL CREW SAFETY AND EFFECTIVENESS

For our final consideration we come now to the most important question under consideration, namely how can we design our manned aircraft in such a manner as will minimize the possibility of operator malfunction of a scope or degree predisposing to accidental destruction. This is the real pay-off in any man–machine–environment configuration; designing the accident potential out of the system while it is still on the drawing boards In the simplest terms we say, *keep the requirements of the system within the known capabilities of the operator to meet them.*

As the speed and complexity of our manned weapon systems have increased, so has our interest and efforts in this field of endeavour, which, for convenience, I call performance and safety engineering. Even the past five years have seen remarkable advances made by the Air Force, Navy and

industry in this area. The Human Factors Team approach, using a fairly broad range of scientific and engineering talent, has been used with some success on the B-47, B-52 and B-58, the century series of fighters, and currently is being applied to the nuclear powered aircraft.

The combined and coordinated efforts of the three groups mentioned above have already yielded results of great value to our basic objective as indicated by the following examples.

(I) Cockpit configurations with component design and positioning to provide operator comfort and ease of operation.

(II) Improved instrument presentation, grouping and lighting for quick and accurate visual reference

(III) Bombing and fire control systems have been extensively studied and re-worked to provide ease and accuracy in both operation and maintenance.

(IV) Operating controls, emergency signals and switches have been designed and located in a fashion which provides immediate identification by visual, aural or tactile sense, and, therefore, reduces materially the likelihood of improper use under normal or emergency operations.

Despite these many significant accomplishments in the field of performance engineering, there is much to be done if we are to materially reduce major incompatibilities between the operator and his aircraft. Examples, such as the fighter aircraft with the radio so placed as to require both the visual attention and the right hand in order to change channels during a let-down procedure, still persist to stimulate us to even greater efforts.

There are a number of valid understandable reasons why, despite our best efforts, some of these man-machine incompatibilities still exist.

(I) We need much more knowledge of man's capabilities and his specific tolerance to over-loading by the system.

(II) We need much more precise information on the requirements of the system for effective and safe operation over the complete range of normal and emergency conditions

(III) We need better techniques for analyzing the characteristics of a semi-automatic servo-loop system with the human component as the master computor

(IV) We need much more objective feed-back from the operational use of our systems.

(V). We need time to find the right answers and prevent the repetition and carry-over of major errors in design from one system to the next simply because we cannot prove conclusively its fallibility.

Future Trends in Reducing Operator-System Malfunction

Any statements made regarding the future trends in this area must assuredly be accepted as reflecting only my personal views, and in no way indicating the policy or plans of the Air Force. In a sense it might even be said that the following prediction of trends is more a reflection of my hopes than anything else.

(I) The science and practice of performance and safety engineering today requires knowledge and skills not contained in any single profession or trade. The field is far too broad to be covered by a single discipline yet

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l'industrie, les Universités. Nous devons nous affranchir des programmes rétrogrades et prévoir à long terme. Il nous faut beaucoup de dispositifs simulateurs, qui se prêtent bien à l'analyse. Enfin, c'est surtout en profitant, à des fins expérimentales, du nombre considérable d'heures de vol effectuées par l'Air Force pour se maintenir toujours prête au combat et en utilisant des dispositifs d'expérimentation en vol bien adaptés à leur but, que nous pouvons espérer trouver une réponse à toutes ces importantes questions.

References

Caldara, J. D. C. "Aircraft Demands exceed Pilot Capability". *Aviation Week*, January, 25, 1956.

Goodyear Aircraft Corporation, Report on Ejectable Seat Programme (U.S. Navy Contract), June 15, 1955.

Moseley, H G. "Protective Equipment and Emergency Escape". USAF Flying Safety Officers' Conference, AFSAM, November 1–4, 1955.

Webb, W. B. "The Prediction of Aircraft Accidents from Pilot-Centred Measures", *J Aviat. Med* 27, No. 2, April 1956.

V. SOME SPECIAL PROBLEMS

CRASH INJURY RESEARCH, A MEANS FOR GREATER SAFETY IN ACCIDENTS

A. Howard Hasbrook

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This paper presents the philosophy and reasons behind crash-injury research. It also shows that some accidents will occasionally occur, despite the most [illegible]

is used in the design of these—and other—aircraft.

The paper also stresses the fact that the increased seating capacity of the new jet transports will increase the number of persons exposed to death and injury per accident, and that this may increase the fatality rate.

Noted also is the need for accurate and exhaustive investigations to find the *specific* causes of injuries, and the need for *integration* of this data with the medical data, as well as with other information normally obtained during the course of an aircraft accident investigation.

In addition, quantitative (statistical) work, as well as qualitative, is cited as an important part of this research; this, in turn brings out the need for crash injury investigation, on an international scale, of *all* survivable type accidents.

The need for the "pooling" of this information—for analysis and presentation of useful data to *all* safety groups and design engineers—is also indicated.

As death and taxes are inevitable, so are accidents. Certainly, the automobile casualty record in the United States shows that accidents continue to occur, despite better driver-training programs, better highways, better tyres, brakes and stricter speed regulations. The more than 40,000 persons killed and 1,000,000 injured on U.S. highways in 1956 proves this point. Why do accidents happen? Because man is essentially an unpredictable quantity, particularly under conditions of emotional stress.

It is true that civil aviation enjoys a phenomenal safety record in comparison with that of the automobile—it being approximately 40 times safer to fly on a scheduled airliner than to travel a like distance by auto. But this wide variation would not exist if reasonable consideration had been given in earlier years to crash-safety design in automobiles.

If *all* automobiles were equipped with safety belts, and people wore them, adequate door locks (to keep the occupants from cracking their skulls on the [illegible]

past two decades.[1] On an average, there were 63 killed and 28 seriously injured per year.

However, during 1955 alone, there were 9 fatal—domestic—accidents, in which 156 persons died and 39 were seriously injured. Thus, despite the fact that the airline fatal accident rate trend (per passenger mile) were generally downward, *more people were killed and injured in 1955 than the average for the preceding 20 year period.*

This increase, of course, is partly due to the increased passenger capacity of our current aircraft—as many as 100 persons in a tourist aircraft—as compared to the 21 passenger capacity of the old DC-3.

As aircraft seating capacities *increase*, the number of persons exposed to death and injury, per accident, will also *increase*. This exposure rate becomes frightening when one realizes that tourist configurations of some new jet transports are expected to accommodate 230 persons, or more. It is obvious that it would require only a few severe accidents to these aircraft to jump the death and seriously injured rates drastically.

According to what crash-injury research has taught us in the past few years about preventing death and injury in survivable type accidents, it is also obvious that *many of the fatal and serious injuries sustained in airline accidents in the last 20 years were unnecessary!* In 1955, for example, 22 per cent of the *fatal* accidents involved *survivable* conditions of crash force—and resulted in 19 per cent of the year's fatalities and 79 per cent of the serious injuries.[2] The remaining 78 per cent of these accidents were of a *non-survivable* nature, in which the aircraft struck the steep sides of mountains at cruising speed, or were otherwise demolished by impact force.

Something can be done to prevent unnecessary death and injury in survivable accidents if we accept the premise that some accidents will occur occasionally, in spite of our best afforts to prevent them. Certainly, our safety record shows that we have been unable to prevent all accidents, despite our increased technical experience and "know-how". This is because we are dealing with an art that is continually changing, as we fly higher and faster, and because we are confronted with the psychological effect of the thousands of human beings involved in the design, construction, maintenance [illegible] make mistakes [illegible]

sort?

Naturally, accident investigation has been, and continues to be, one of the greatest deterrents to the *duplication of accidents, for once the basic cause of an accident is known,* additional efforts can be made to prevent a similar —causative—situation. *Likewise, investigation aimed at finding the specific causes of injury in accidents can prevent the recurrence of such injuries in future accidents —by engineering design.* This is the reason for, and the basic principal of, crash-injury research and crash-safety design.

To achieve this goal of safety in survivable accidents, much work must be [illegible] relating to in- [illegible] and [illegible] air-craft, seats and other interior equipment, the extent and type of damage to

the structural environment of the occupants, the impact forces involved, and hundreds of other such details.

To illustrate this in a simple manner, let us imagine two persons riding side by side in an automobile The car is involved in an accident; the driver is not injured but the passenger is killed. Immediately the question arises as to why there is such a difference of injury in one accident. Is it because of luck, a rabbit's foot or God's will? Fortunately, as we will see, none of these is the answer. Investigation of the damage to the automobile, the design of the interior of the vehicle, and the type and site of injuries will provide the answer—*an engineering answer!*

Investigation may show, for example, that the front of the vehicle had struck a stone wall at about 20 miles/hr and had received extensive damage, the forward structure was telescoped about 24 in , but the inhabitable area of the automobile remained completely intact. Analysis would show that appreciable crash force—6 8 G—had been involved. In addition, although the accident was severe, it was survivable because (I) the occupied area of the vehicle was not collapsed and, (II) the deceleration was well within the tolerance of the human body [3, 4, 5]

What were the reasons for the fatal injury of the passenger and the lack of injury to the driver? The medical report might show that the passenger sustained a depressed fracture of the forehead over the right eye, with brain damage.

In relation to the driver's lack of injuries, further investigation might show that the steering wheel had been designed to (I) distribute and "soften" a crash blow to the driver's chest and (II) restrain him from striking the windshield area. On the other hand, detection of a small, rigid, sunshade attachment in the area struck by the passenger's head would provide a clue to the cause of the fatal head injury—since the free flung head would not decelerate until it struck the sunshade attachment, the resulting deceleration of the head would be much greater than that of the vehicle—perhaps 300 G or more. If the sunshade attachment had a frontal area of 0·5 in^2, the load imposed on the skull would equal at least 6000 lb/in^2.

Thus, the investigation and analysis of this auto accident would provide information on (I) the value of the crash-safety design of the steering wheel and (II) the injury potential of the sunshade attachment, thereby providing the means of eliminating such head injuries in future accidents in this vehicle—by redesigning, relocating or padding this piece of hazardous hardware.

This is an over-simplified example of the basic procedures in conducting crash-injury research on aircraft accidents—evaluating (I) the accident condition in respect to force, (II) the type and design of the occupant's environment, (III) the degree of damage to the vehicle and to the occupant's structural environment and, lastly, (IV) the injuries sustained by each occupant. In almost every case, the exact cause of injury can be found. *Likewise, the reasons for survival and lack of injury can also be ascertained.*

When such data is properly analyzed and presented in meaningful terms, to safety groups and engineers, it permits the *integration of good crash-safety design* in future aircraft, and the *exclusion of hazardous design.*

Before reviewing the results of some crash-injury investigations conducted

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Naturally, accident investigation has been, and continues to be, one of the greatest deterrents to the duplication of accidents, for once the basic cause of an accident is known, additional efforts can be made to prevent a similar —causative—situation. *Likewise, investigation aimed at finding the specific causes of injury in accidents can prevent the recurrence of such injuries in future accidents —by engineering design.* This is the reason for, and the basic principal of, crash-injury research and crash-safety design.

To achieve this goal of safety in survivable accidents, much work must be ... relating to in- ... h and ... ie air-craft, seats and other interior equipment, the extent and type of damage to

the structural environment of the occupants, the impact forces involved, and hundreds of other such details.

To illustrate this in a simple manner, let us imagine two persons riding side by side in an automobile. The car is involved in an accident; the driver is not injured but the passenger is killed. Immediately the question arises as to why there is such a difference of injury in one accident. Is it because of luck, a rabbit's foot or God's will? Fortunately, as we will see, none of these is the answer. Investigation of the damage to the automobile, the design of the interior of the vehicle, and the type and site of injuries will provide the answer—*an engineering answer!*

Investigation may show, for example, that the front of the vehicle had struck a stone wall at about 20 miles/hr and had received extensive damage; the forward structure was telescoped about 24 in., but the inhabitable area of the automobile remained completely intact. Analysis would show that appreciable crash force—6.8 G—had been involved. In addition, although the accident was severe, it was survivable because (I) the occupied area of the vehicle was not collapsed and, (II) the deceleration was well within the tolerance of the human body.[3,4,5]

What were the reasons for the fatal injury of the passenger and the lack of injury to the driver? The medical report might show that the passenger sustained a depressed fracture of the forehead over the right eye, with brain damage.

In relation to the driver's lack of injuries, further investigation might show that the steering wheel had been designed to (I) distribute and "soften" a crash blow to the driver's chest and (II) restrain him from striking the windshield area. On the other hand, detection of a small, rigid, sunshade attachment in the area struck by the passenger's head would provide a clue to the cause of the fatal head injury—since the free flung head would not decelerate until it struck the sunshade attachment, the resulting deceleration of the head would be much greater than that of the vehicle—perhaps 300 G or more. If the sunshade attachment had a frontal area of 0.5 in^2, the load imposed on the skull would equal at least 6000 lb/in^2.

Thus, the investigation and analysis of this auto accident would provide information on (I) the value of the crash-safety design of the steering wheel and (II) the injury potential of the sunshade attachment, thereby providing the means of eliminating such head injuries in future accidents in this vehicle—by redesigning, relocating or padding this piece of hazardous hardware.

This is an over-simplified example of the basic procedures in conducting crash-injury research on aircraft accidents—evaluating (I) the accident condition in respect to force, (II) the type and design of the occupant's environment, (III) the degree of damage to the vehicle and to the occupant's structural environment and, lastly, (IV) the injuries sustained by each occupant. In almost every case, the exact cause of injury can be found. *Likewise, the reasons for survival and lack of injury can also be ascertained.*

When such data is properly analyzed and presented in meaningful terms, to safety groups and engineers, it permits the *integration of good crash-safety design* in future aircraft, and the *exclusion of hazardous design.*

Before reviewing the results of some crash-injury investigations conducted

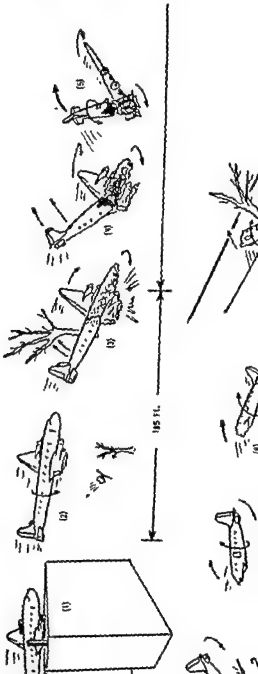

Fig 2. The floor and seat attachments failed eleven of the thirty-two passengers were fatally injured

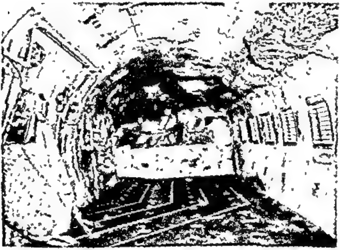

Fig 3 The anchorages on the rearward facing seats tore free from this intact floor numerous persons died

Fig 4 Despite destruction of the belly structure, the floor remained intact

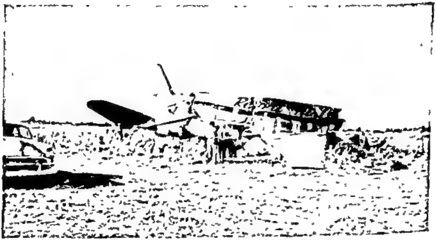

Fig 5 This transport struck the ground in excess of 150 mph about 40° nose down, sixteen of the thirty-eight passengers survived

Fig 6 The spear-like tubes in the seat-backs were related to fatal head injuries of eleven passengers

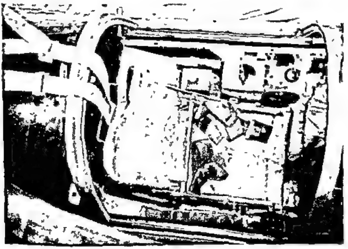

Fig 7 The bottom and back of this 40 g seat partially failed the pilot sustained serious injuries

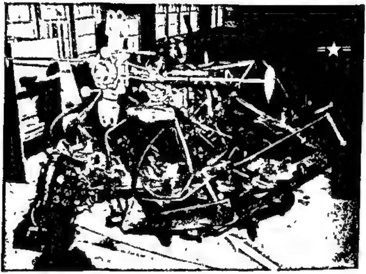

Fig 8. The pilots of this helicopter sustained a minimum vertical deceleration of 28 G: both survived—neither sustained spinal injury

survived The injuries and deaths that occurred were caused by inward collapse of the aircraft structure which crushed many of the occupants in their seats. *The safety belts caused no serious, internal injuries.*

In another accident[7] (*Fig.* 2), approximately one-third of the passengers were killed, many others had critical injuries. The deaths and injuries were due to failure of the seats and seat attachments, as well as to failure of *rigid* safety belt anchorages. In addition, it was found that the principal crash force—apparently in excess of 16 G—was directed *upward* from an angle of about 60°. It appears that this vertical force was a primary factor in producing the lumbar spine injuries suffered in this accident.

It was also shown that the use of lightweight floor structure, in combination with vertical braces extending between the belly of the aircraft and the floor, contributes to seat failure, when the belly is crushed upward during a crash landing.

In another severe accident[8] involving a four-engine transport equipped with *aft* facing seats, the rear half of the passenger cabin (including the floor structure) remained completely intact (*Fig.* 3), despite disintegration of the entire belly structure (*Fig.* 4). However, all of the aft facing seats, with their occupants, tore free from the intact portion of the cabin. The passengers became missiles and many were killed or injured simply because the *rigid* seat attachments failed in a deceleration which one agency concluded was less than 10 *G*.

In another transport accident[14] (*Fig.* 5), the aircraft struck the ground about 40° nose down, in excess of 150 miles/hr, 16 of the 38 cabin occupants survived, *some with minor injuries.* All 22 deaths were reportedly due to head injury; 50 per cent of these involved depressed fractures and/or puncture wounds of the skull and brain, due to impingement against sharp steel tubes in the seat backs (*Fig* 6). The lack of delethalization and of a "break-over" feature in the seat-backs were the factors directly related to the cause of these fatal head injuries.

In a recent military, fixed-wing trainer accident, in which the rear seat occupant survived with *non*-dangerous injuries, the 40 G seat failed at two points, i e. at the top where the shoulder harness webbing crossed over the seat-back and at the forward corners of the seat-pan (*Fig.* 7). Also, the control stick failed at its attachment near the floor, preventing serious chest

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Fig 1 Reconstruction of kinematics of a transport crash.

(1) *Aircraft bellies onto roof of apartment house Right outer wing panel tears off*
(2) *Plane starts rolling to right Number 4 engine drops to ground*
(3) *Rear cabin starts jackknifing upward at rear spar as plane strikes ground*
(4) *Jackknifing continues and cabin begins to break free as the forward cabin disintegrates and the centre section starts cartwheeling*
(5) *Rear cabin continues to tear loose during cartwheeling action*
(6) *Rear cabin tears completely loose in a "snap-the-whip" action as it starts rolling to the right and turning on its own CG*
(7) & (8) *Centre section continues cartwheeling as rear cabin rolls and turns in "Flight"*
(9) *Centre section comes to rest and burns after having cartwheeled more than 180°*
(10) *Rear cabin still in "flight" strikes tree while partially inverted and rolling on its longitudinal axis, cabin breaks into two portions and comes to rest around tree*
(11) *Seat thrown from rear cabin during impact with tree*

17

injuries. From a crash-injury point of view, this accident demonstrated principally (I) that the crashworthiness of the cockpit structure exceeded 40 G, (II) that seat modifications were necessary, to prevent failure in similar accidents, and (III) the design criteria for the control stick attachment could very well be used in other aircraft, to prevent chest injury.

Fig. 8 shows a helicopter that crashed from an altitude of 150 ft after major portions of the rotor blades disintegrated.[17] Both occupants survived. *Although the vertical force in this accident was in the range of 28 to 73 G, neither occupant sustained any injury to the spine.* Crash-injury analysis indicated that this lack of spinal injury was probably due to several factors: (I) the seat-pans were of a light, sheet-metal construction which collapsed in such a manner that the crash load was distributed "evenly" over the buttocks; (II) the rear portions of the seats collapsed downward more than the front, causing the occupants to jackknife acutely at the hips and preventing an abnormal flexing of the lower spine. In addition, (III) at the time the principal crash force was imposed, the weight of the upper torso was apparently borne by the thighs effectively *reducing the compressive loading of the spine.*

The survival of these occupants is not considered unusual, despite the high G deceleration, since previous research[3] has shown that the human body can withstand decelerations of 150 G without dangerous injury, provided (I) the crash loads are distributed in a reasonably uniform manner over the body, and (II) the duration of such loads is short, from 0·01 sec to 0·10 sec. The duration of the crash load in this helicopter accident was approximately 0·06 sec.

The data relating to this lack of spinal injury in combination with such heavy vertical force may also be useful to designers of ejection seats for fighter aircraft, either in relation to the design of seat-pans, or the possible tilting of the seat so that the acceleration—ejection—load is imposed transversely to the spine.

These are examples of *qualitative* crash-injury and crash-survival data that can be extracted from survivable aircraft accidents; data which are useful in preventing injury, by engineering design, in future accidents. However, this research also involves *quantitative* (statistical) investigation. The statistical phase is not an end in itself, but serves to point out areas requiring crash-safety design consideration. For example, without valid statistics showing that the head is seriously injured more often than any other part of the human body,[18] engineers would not have known which portion of the anatomy primarily required safety consideration. Thus, statistical evaluations are an important part of crash-injury research.

To effectively use crash-injury and crash-survival information, it is necessary to present it in meaningful form. To do this, Aviation Crash Injury Research uses a statistical code divided into three basic parts, each containing hundreds of details. The first basic part relates to the degree of severity of the force condition in which the aircraft is involved. Data in this, for example, relate to the weight and configuration of the aircraft, the attitude of the aircraft at impact, the velocity of impact, the direction of force, the type of terrain on which the impact took place, the strength of the structural environment of the occupant, and so on. The second part relates to the severity of impact damage to the inhabitable area of the aircraft, as well as to the

damage to each occupant's immediate area. This also includes data on the degree of crushing of the immediate structure, damage to the seats and anchorages, condition of the safety belts, and other related information. The third part consists of an evaluation of the injuries sustained by each person, these are divided roughly into ten degrees,[19] of which the last four relate to the *relative degree of fatality*. The first six degrees of injury provide an indication of the severity of injury—in relation to life expectancy (see Av-CIR Injury Code in Appendix). This provides a meaningful difference between such "serious" injuries as fractured legs and fractured skulls—the latter, of course, being much more serious than the former

When sufficient data is accumulated, this code can point the engineer's attention to both the broad, and the detailed, design areas requiring prime crash-safety design consideration.

To obtain all the data necessary for a well planned attack against unnecessary death and injury in survivable crashes, accident investigators, safety engineers, design engineers, doctors and pathologists must aid each other in obtaining the information necessary for analyses Then some means must be found to direct this data from each accident investigation to one group experienced in the analysis and reporting of such data Only in this way can needed information from accidents, regardless of where they occur in the world, be made available for effective use by all safety groups and engineers in *all* countries.

Aviation ideally recognizes no geographical boundaries, neither should the development of crash protection be hampered by geographical boundaries, for regardless of our nationality, we are all striving for the preservation of human life.

Degrees of Injury Used by Av-CIR*

I Degrees †	‡	
1—	1	*Trivial or none*
4—	2	*Minor*

"Minor" contusions, lacerations, abrasions in any area(s) of the body. Sprains, fractures, dislocations of fingers, toes or nose. Dazed or slightly stunned Mild concussion evidenced by mild headache, with no loss of consciousness.

15—	3	*Moderate—but not dangerous.*

"Moderate" contusions, lacerations, abrasions in any area(s) of the body. Sprains of the shoulders or principal articulations of the extremities. Uncomplicated, simple or green-stick fractures of extremities and jaw Concussion as evidenced by loss of consciousness not exceeding 5 min, without evidence of other intracranial injury.

*Based on observations during first 48 hr after injury and previously normal life expectancy.
†Weighted value for degrees of total injury.
‡Degrees of total injury

28— 4 *Severe—but not dangerous.*

Survival normally assured. Extensive lacerations without dangerous hemorrhage. Compound or comminuted fractures, or simple fractures with displacements. Dislocations of the arms, legs, shoulders or pelvisacral processes. Fractures of the facial bones. Severe sprains of the cervical spine. Fracture of transverse and/or spinous processes of the spine, without evidence of spinal cord damage. Simple fractures of vertebral bodies of the dorsal and/or lumbar spines, without evidence of spinal cord damage Compression fractures of L–3–4–5. Skull fracture without evidence of concussion or other intracranial injury. Concussion as evidenced by loss of consciousness of over 5 and up to 30 min, without evidence of other intra-cranial injury

45— 5 *Serious—dangerous, but survival probable.*

Lacerations with dangerous hemorrhage. Simple fractures of vertebral bodies of the cervical spine, without evidence of spinal cord damage. Compression fractures of vertebral bodies of

intra-abdominal injury. Skull fracture with concussion as evidenced by loss of consciousness up to 30 min. Concussion as evidenced by loss of consciousness of over 30 min to 2 hr, without evidence of other intracranial injury.

66— 6 *Critical—dangerous, survival uncertain or doubtful.*

(Includes fatal terminations beyond 24 hr.) Evidence of dangerous intrathoracic or intra-abdominal injury. Fractures or dislocations of vertebral bodies of cervical spine with evidence of cord damage. Compression fractures of vertebral bodies of dorsal spine, and/or L–1, L–2, with evidence of spinal cord damage. Skull fracture, with concussion as evidenced by loss of consciousness, beyond 30 min. Concussion as evidenced by loss of consciousness beyond 2 hr. Evidence of critical intracranial injury.

91— 7 *Fatal—within 24 hr of accident.*

Fatal lesions in single region of the body, with or without other injuries to the fourth degree.

120— 8 *Fatal within 24 hr of accident.*

Fatal lesions in single region of the body, with other injuries to fifth or sixth degree.

153— 9 *Fatal.*

Fatal lesions in two regions of the body, with or without other injuries elsewhere.

190— 10 *Fatal.*

Fatal lesions in three or more regions—up to and including demolition of the body.

(Revised August, 1958).

Sommaire

Nécessité des recherches sur les lésions provoquées par accidents d'avion, non mortelles, en combinaison avec des études détaillées d'ordre structural, médical et pathologique. Discussion des résultats des enquêtes déjà effectuées et utilisation qui en a été faite pour la conception des avions de transport à hélice pour la période actuelle et à réaction pour l'avenir.

De même, sont rapportées plusieurs enquêtes d'accidents récents (dont un hélicoptère) et sont relatées quelques constatations typiques pour illustrer la grande valeur des renseignements techniques et médicaux qui peuvent être tirés de ces accidents au bénéfice des avions futurs

References

1 From Reports by the Civil Aeronautics Board.

2 Crash Survival Studies by Aviation Crash Injury Research of Cornell University.

3 De Haven, H "Mechanical Analysis of Survival in Falls from Heights of Fifty to One Hundred, Fifty Feet". "*War Medicine*", 2, pp. 586–596, Cornell University, July 1942

4 Stapp, J P. "Human Exposures to Linear Deceleration Part 2—The Forward Facing Position and the Development of a Crash Harness" (USAF Technical Report No. 5915, Part 2, 12/51) report issued through Wright Air Development Center Wright–Patterson Air Force Base, Dayton, Ohio.

5 Hasbrook, A H. "Crash Survival Study of a Survivable Accident Involving a Piper PA-11". Aviation Crash Injury Research of Cornell University.

6 Gurdijan, E. S., Webster, J. E., Lissner, H. R. and Gaynor Evans, F Reports, Wayne University

7 Hasbrook, A. H "Photographic Report of American Airlines Convair accident at Springfield, Missouri". Aviation Crash Injury Research of Cornell University.

8 Hasbrook, A. H "Design of Passenger Tie-Down", (Section I of Av-CIR Crash Design Manual). Aviation Crash Injury Research of Cornell University.

9 Military Air Transport (MATS) C-118 accident at McGuire Air Force Base, Trenton, New Jersey, July 13, 1956.

10 Italian Airlines (LAI) DC-6B accident at Idlewild Airport, N Y., December 19, 1954.

11 Hasbrook, A. H. "Crash Survival Study. National Airlines DC-6 Accident at Elizabeth, New Jersey, February 11, 1952". Aviation Crash Injury Research of Cornell University.

[12] Av-CIR Crash Safety Design Manual.

[13] NACA Crash Test Reports:

(a) NACA Conference on Airplane Crash-Impact Loads, Crash Injuries and Principles of Seat Design for Crashworthiness.

(b) PESMAN, G. P. and EIBAND, A. M. "Crash Injury"

(c) PINKEL, I. I. and ROSENBERG, E. G. "Seat Design for Crashworthiness."

(d) EIBAND, A. M., SIMPKINSON, S. H. and BLACK, D. O. "Accelerations and Passenger Harness Loads Measured in Full-Scale Light-Airplane Crashes".

[14] Resort Airlines C-46 accident at Louisville, Ky., Sept. 28, 1953.

[15] STAPP, J. P. Deceleration Tests at Holloman Air Force Base, USAF.

[16] HASBROOK, A. H. "Crash Survival Study: De Havilland Dove Accident at Staten Island Airport, December 9, 1952". Aviation Crash Injury Research of Cornell University.

[17] HASBROOK, A. H. "Analysis and Photographic Report of a Bell H-13 accident at Monmouth County Airport, New Jersey, June 13, 1956". Aviation Crash Injury Research of Cornell University.

[18] DE HAVEN, H. "The Site, Frequency and Dangerousness of Injury Sustained by 800 Survivors of Lightplane Accidents." Aviation Crash Injury Research of Cornell University, July 1952.

[19] "Degrees of Injury Used by Av-CIR". Aviation Crash Injury Research of Cornell University.

LIMITES DES PRONOSTICS FONDES SUR LES TESTS PSYCHOMOTEURS

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Dans la perspective d'une efficacité contrôlable par les résultats des écoles de pilotage la sélection psychologique des candidats parvient à une rentabilité immédiate indiscutable.

Cependant, faute d'autre critère professionnel valable, les méthodes de sélection qui se réfèrent en termes de probabilités aux résultats des écoles confèrent par là même la responsabilité majeure de la sélection à la doctrine d'entraînement et au degré d'objectivité de son contrôle Pour estimer la [illegible]

logique.

La question préalable vise le degré d'accord entre les exigences de différentes écoles de pilotage, le problème est ici posé pour les écoles de chasse de trois pays de l'OTAN

D'autre part le rythme accélére de ce type d'entraînement lie inévitablement l'adaptation des élèves à leur formation préalable sans qu'il soit possible de déterminer dans quelle mesure les acquisitions peuvent refléter motivation ou aptitudes. En fait certains antécédents biographiques et en particulier *ceux qui impliquent une formation technique influent très largement sur les* performances aux tests et cela semble une condition majeure de leur validité.

Cette constatation paraît moins évidente pour les tests psychomoteurs qui pourraient être considérés comme reflétant des aptitudes innées, cependant les performances psychomotrices peuvent être démontrées plus ou moins liées à la formation préalable et la notion de transfert des apprentissages passés semble mieux rendre compte des faits que ne pourraient le faire d'hypothétiques aptitudes.

Validité des Tests Psychomoteurs par Rapport à Différentes Écoles de Pilotage

Les tests psychomoteurs étudiés ici sont ceux de la batterie américaine. [illegible]

Les critères étudiés ici sont 2135 résultats d'élèves pilotes français brevetés ou éliminés dans les écoles canadiennes, américaines et françaises; ces résultats concernent donc des écoles où les conditions d'entraînement sont théoriquement comparables.

plus approfondies. Il apparait ainsi que les tests les plus valides au stade élémentaire deviennent les moins valides au stade chasse et inversement. Cette constatation est d'ailleurs confirmée à partir des tests écrits de la batterie pilote et d'autres batteries. Cela a été retrouvé par les corrélations relativement faibles entre les deux critères et prouve que les exigences de l'école française de chasse sont assez différentes de celles du stade élémentaire=une sélection fondée sur deux batteries a ainsi été rendue nécessaire.

La validité maximum de l'ensemble des tests psychomoteurs est cependant la même pour les deux stades (r multiple: 0 37), mais pour cet échantillon elle peut être approximativement obtenue avec trois tests seulement en donnant les poids suivants.

	École élémentaire	*École de chasse*
T.R :	0	2
P C :	0	2
C B	2	1
C P .	1 5	0
C C :	1	0

Ainsi des divergences objectivables peuvent être mises en évidence entre les exigences du stade élémentaire et celles du stade chasse et, bien qu'à la base ces exigences soient relativement comparables pour les écoles des trois pays envisagés, on peut considérer comme assez naïve la conception d'une aptitude au pilotage qui ne se réfèrerait pas à un critère donné

Recherches Concernant la Signification Psychologique des Tests Psychomoteurs

Le problème complexe de l'interprétation psychologique des tests a été envisagé selon deux méthodes. l'analyse factorielle et les sous-groupes à référence biographique

Dans la batterie pilote (tests écrits et tests psychomoteurs) un facteur psychomoteur a pu être isolé, mais son indépendance par rapport aux autres facteurs n'est que très relative. Un seul test, la P.C s'est révélé purement psychomoteur en ce sens qu'il n'est saturé dans aucun autre facteur. Le test T.R. est par contre le moins psychomoteur et il appartient aussi bien au facteur de niveau intellectuel et scolaire. Le test C P. est le plus difficile à interpréter car il a une faible communauté avec la batterie. Le *Tableau II*

Tableau II Saturations dans les quatre Facteurs de la Batterie Pilote Extrait de la Matrice des Facteurs après Rotation

Tests	*Facteur psychomoteur*	*Facteur expérience mécanique*	*Facteur connaissances aéronautiques*	*Facteur intellectuel et scolaire*
P C	0 56	—	—	—
T R	0 36	—	—	0 39
C C	0 54	0 24	—	—
C B	0-45	0 32	—	—
C.P	0 39	—	0 14	—
Test expérimental	0 78	—	—	—

donne les saturations des tests psychomoteurs seulement, et pour plus de clarté les saturations pratiquement nulles ne sont pas mentionnées.

Un test expérimental, le test de coordination du Médecin-Général Placidi a été introduit dans cette analyse factorielle et on peut constater qu'il est très saturé dans le facteur psychomoteur=c'est le test qui a le plus de communauté avec l'ensemble de la batterie et il semble ainsi pouvoir remplacer plusieurs tests.

Cette structure factorielle concerne les candidats au pilotage, une structure assez voisine a été retrouvée avec la population des élèves-pilotes admis en école élémentaire. Dans ce dernier cas la corrélation entre le facteur psychomoteur et le facteur représentant des connaissances aéronautiques et mécaniques est de: 0·33. Dans cette dernière étude factorielle ont été intégrées des données biographiques groupées selon la méthode des "clefs homogènes"; parmi ces groupements dont la validité a été éprouvée deux "clefs" reflétant des intérêts techniques et aéronautiques des sujets ont donné des corrélations très significatives avec les tests CC, CB et CP; les corrélations sont par contre nulles avec les tests RT et PC que l'on peut voir dans le *Tableau II* indépendants des acquisitions techniques.

Une autre méthode permettant d'étudier l'influence de la formation préalable sur les performances psychomotrices a isolé dans la population des candidats au pilotage un certain nombre de sous-groupes d'appartenances diverses dans le domaine de la scolarité, des antécédents professionnels, des activités extraprofessionnelles.

A titre d'exemple quatre sous-groupes seulement sont cités ici, ils ont été choisis parce qu'ils sont les plus privilégiés et sont les plus représentatifs des facteurs de réussite. Ces quatre sous-groupes concernent: formation scientifique appliquée à l'aéronautique, formation technique élémentaire, formation aéronautique très élémentaire en aéro-club, formation scolaire supérieure.

Tableau III. Performances Moyennes de Quatre Sous-groupes Privilégiés Écart en Stanine par Rapport à l'Ensemble des Candidats au Pilotage

Tests	*Elèves de l'école sup d'aéronautique*	*Candidats issus des écoles Nles professionnelles*	*Candidats ayant volé en aéro-club*	*Candidats à l'Ecole de l'Air*
P C	+0 86	+0 74	+0 53	+0 82
T R.	+1·79	+0 05	−0 06	+1 15
C.C.	+1 88	+1 44	+0 63	+1·32
C B	+1·46	+0 92	+0·79	−0 16
C P.	+2 08	+1 84	+2 44	+0·44

Ces données confirment celles de l'analyse factorielle, les tests CC, CB et CP favorisent le plus les candidats qui ont reçu une formation technique avec [illegible] Les performances au [illegible] point [illegible] ions [illegible] d'origine. Ces quatre sous-groupes sont d'ailleurs privilégiés de plus d'un stanine dans le facteur psychomoteur de la batterie. D'autres sous-groupes

voisins permettent des constatations analogues et cela indique grossièrement l'influence des apprentissages préalables sur les performances psychomotrices, avec la réserve que l'on ne peut apprécier le rôle de la motivation ou des aptitudes dans le choix des activités citées. Il faut noter cependant que les références biographiques sont très sous-estimées puisqu'il faudrait constituer des sous-groupes de sous-groupes pour parvenir à une meilleure approche des conditions de milieu.

L'effet d'apprentissage peut encore être étudié en comparant deux passations des tests à 6 mois d'intervalle. Cet effet d'apprentissage est beaucoup plus important pour les tests psychomoteurs que pour les tests écrits et il est intéressant de noter que c'est le test le plus psychomoteur de la batterie, la PC, qui donne le plus grand écart, les performances étant presque doublées à la deuxième passation.

Gain standard Obtenu à une Deuxième Passation des Tests

PC	*TR*	*CC*	*CB*	*CP*
1 85	1 26	1 60	1 51	1 39

Ainsi nous sommes loin des qualités innées des supposées aptitudes psychomotrices et nous allons montrer que c'est précisément parce que ces tests reflètent des acquisitions qu'ils sont valides.

Interprétation de la Validité des Tests en Fonction de Leur Signification Psychologique et des Exigences des Écoles

[illegible]

facteurs de la batterie, mais l'étude n'a pas encore été faite pour le stade chasse.

Les interprétations concernant la validité de chaque test ne pourraient être données à partir des seuls tests psychomoteurs mais ce qui les rend possibles c'est la concordance avec les résultats de nombreux autres tests ou questionnaires biographiques.

L'hypothèse à confirmer est que si les tests psychomoteurs reflètent dans une certaine mesure les expériences passées, cela peut être considéré comme une condition de leur validité. Cette hypothèse repose en grande partie sur le fait que l'entraînement accéléré des écoles de pilotage de l'OTAN opère inévitablement une sélection largement fonction de la formation technique préalable des élèves.

Si l'on compare les *Tableaux I, II* et *III*, il apparaît que le test CP qui [illegible]

bénéfice des apprentissages préalables s'est atténué. Cette constatation est

particulièrement valable pour l'entraînement américain et à un moindre degré pour l'entraînement français, mais il faut noter qu'avant le stade élémentaire se situe un stage dit de "dégrossissage" pour lequel ce test atteint une forte validité. Ainsi une telle validité n'aurait de signification rigoureuse que si elle était établie sur des populations n'ayant aucune expérience préalable du vol, mais cela pourrait être dit aussi de bien d'autres activités transférables au domaine aéronautique. Par ailleurs toute interprétation fondée sur l'aspect motivationnel des acquisitions ne pourrait demeurer que très aléatoire puisque l'on ne peut envisager de faire un bilan des conditions de milieu.

En ce qui concerne les exigences relativement divergentes des stades élémentaire et chasse des Ecoles françaises, on pourrait poser l'hypothèse que les différences des validités obtenues sont dues au fait que l'entraînement sur réacteur exige des aptitudes différentes de celles de l'entraînement sur avion à hélice Cependant les arguments contre cette thèse sont nombreux. Un premier argument est d'ordre logique, le fait d'étudier isolément un stade avancé où les élèves sont de plus en plus sélectionnés par des éliminations successives ne permet pas d'attendre à partir des mêmes données des pronostics aussi valables que pour le stade élémentaire, ceci est d'ailleurs bien mis en évidence par les validités américaines citées, celles-ci sont très abaissées au stade "Jet". Un autre argument majeur vise les exigences propres à l'école française de chasse, exigences qui sont très liées au niveau intellectuel et scolaire. Au contraire le stade élémentaire français est beaucoup moins exigeant à cet égard de même que les écoles américaines et canadiennes. Cela ne correspond cependant pas à des aptitudes spécifiquement aéronautiques et relève du niveau scolaire du recrutement Ces constatations ont été faites à partir de nombreux tests, l'aspect psychomoteur [illegible] L'exemple [illegible] ialisation [illegible] ant aussi [illegible] -ur de la batterie.

Le test P.C. qui a aussi une relativement forte validité pour l'école française de chasse pose un problème qui n'a pu encore être résolu. Il s'agit en effet d'un test factoriellement pur au point de vue psychomoteur et qui à notre connaissance discrimine le moins selon les activités préalables. On pourrait ainsi. au stade de nos connaissances, parler d'aptitude si ce n'était [illegible]

quatre phases dont deux avec "attention diffusée". Les validités [illegible] quatre phases s'établissent ainsi pour le stade chasse:

[illegible] *r bis* : 0·18
[illegible] *r bis* : 0 25
[illegible] *r bis* : 0 28
[illegible] *r bis* : 0·18

Les phases avec "attention diffusée" étant les plus valides pouvaient être

pensées faire appel à des fonctions psychomotrices plus élaborées et ainsi plus liées au niveau intellectuel, mais cette hypothèse n'a pu être confirmée car les deux tâches sont très étroitement corrélées (r : 0 82).

Ainsi, hormis en ce qui concerne le test PC, la validité des tests psychomoteurs peut être démontrée assez largement liée à la formation préalable même grossièrement appréciée. Si les tests mesurent tous plus ou moins la rapidité d'adaptation à des tâches variées les connaissances ou les apprentissages préalables transférables sont fortement valorisées, et c'est aussi le cas dans les écoles de pilotage à rythme d'entraînement accéléré

Limite des Pronostics Psychologiques

Le critère de l'entraînement au pilotage est trop complexe et par là même trop peu objectif pour prétendre à de très fortes validités. Il semble même qu'il y ait une certaine disproportion entre les techniques très raffinées de la psychologie appliquée et le degré de consistance des jugements de valeur auxquels on se réfère La méthode des tests peut d'ailleurs permettre 'estimer le degré d'organisation d'un système en ce sens qu'un système mme celui de l'entraînement est d'autant plus prédictible que son organi- ion est plus stable.

La complexité du critère se retrouve dans l'intrication des causes d'élimi- ation des écoles et on peut dire des échecs qu'ils sont "expliqués" dans la mesure où ils pouvaient être prévus Une étude qui a cherché, d'après les dossiers d'école, à isoler les causes d'élimination n'a réussi à mieux objectiver que l'insuffisance en vol. Cette raison qui est donnée pour les 3/4 des échecs est en effet mieux prédite que l'ensemble des éliminations, mais il ne s'agit là que d'une catégorie très grossière et il est par ailleurs difficile d'analyser davantage les phénomènes tant que les méthodes objectives de testing en vol ne sont pas plus développées Sur 1069 élèves pilotes française entraînés aux U.S.A les validités suivantes ont été obtenues à partir de la batterie pilote d'origine·

Tous éliminés :	*r bis* 0 40		
Eliminés pour insuffisance en vol	*r bis* : 0 50	tests psychomoteurs	0 45
		test écrits	0 39

Ainsi ce sont beaucoup plus les critères que les tests qui posent les problèmes majeurs 'e sélection—L'objectivité du critère peut être considérée sous deux aspects bjectivité du contrôle de l'entraînement qui conditionne la validité des sts, objectivité des valeurs impliquées par les méthodes de formation. Ce rnier aspect n'aurait de sens psychologique que dans la perspective d'un idement professionnel ultérieur, ce qui est difficilement étudiable actuelle- nt faute de critère valable. A défaut de celui-ci les pronostics d'école de tage sont faits à partir de groupes de formation préalable hétérogène la est inévitable et correspond aux exigences d'un entraînement qui, ne ant être individualisé, favorise d'autant plus certains groupes que son ne est plus accéléré. Un tel système sélection-entraînement qui permet lement de valoriser des caractéristiques individuelles n'est pas en de la possibilité d'une sélection dont la validité dépasserait les stades s.

Conclusion

[illegible]

la mesure où ils reflètent des apprentissages préalables. Cependant aptitudes aussi bien que motivation sont plus ou moins impliquées dans le choix des activités passées, mais ces aspects ne peuvent être isolés et pour avoir un intérêt expérimental ils nécessiteraient des critères beaucoup plus simples et indépendants des acquisitions techniques qu'ils ne sont en réalité dans le domaine aéronautique.

La méthode des tests répond surtout aux impératifs économiques d'un entraînement accéléré, elle permet une approche expérimentale des exigences du pilotage et tend à un inventaire des acquisitions passées qui correspondent le mieux à ces exigences.

En cherchant à expliquer au maximum les performances aux tests et la réussite en école de pilotage par le contexte biographique nous avons limité la portée des pronostics psychologiques à longue échéance et nous avons dévalorisé l'aspect magique de la sélection. Nous avons par contre mis l'accent sur l'apprentissage et nous avons ainsi sous-entendu que dans la perspective expérimentale l'aspect psychologique essentiel est celui des méthodes de formation

Summary

Tests in general and psychomotor tests in particular, seem to be valid with regard to the results of flying training in so far as they reflect previous learning linked with conditions of social environment. Does the fact of minimizing thus individual characteristics allow a selection that would still be valid on the job criterion?

(I) Validity of psychomotor tests with regard to various flying training schools— the tests which are studied here are those of the American battery "Aircrew Classification Battery" adapted to the French population. The validities of psychomotor tests are given for the flying training schools of three NATO countries in which our students have been trained: USA, CANADA, FRANCE. The most pronounced disagreement between the requirements of these schools concerns the French advanced fighter training school in which intellectual capacities are much more valorized than in other schools.

(II) Researches concerning the psychological significance of psychomotor tests— the psychological interpretation of the tests has been made through:

the factor analysis of the battery.

biographical inventories studied with the method of "homogeneous keys", these keys having been introduced into a factor analysis of the battery.

the study of the performance in the tests and in each factor of various subgroups, some of which may be shown to be particularly privileged.

the effect of learning at a second testing.

[illegible] relation to their psychological [illegible]

(IV) Limits of psychological [illegible]

[illegible] *on the job criterion* [illegible] *do not favour the*

Conclusion

The present selection of flyers is largely dependent on their biographical antecedents. It is not possible to discriminate between motivation, aptitude and environment conditions in past activities, but the experimental methods enable us to situate the problems of selection with regard to the economical point of view in training.

By stressing the importance of learning, we understood that methods of training constitute the essential psychological problem.

LEFT-HANDEDNESS AND LATERALITY IN PILOTS

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IN 1953 as our institution became increasingly involved in the problem of pilot errors, we were struck by the idea that the problem of left-handedness

less pronounced history of left-handedness, and their maladjustment seemed to have some connection with their left-handedness. To show the direction of our findings, we will here report six cases.

Case 1

A fighter pilot, second lieutenant, 24 years old, consulted the physician because he did not sleep and did not like his kind of service. He began to drink more liquor [illegible] that this made him feel relaxed.
said he always ha
formation flying. He began to be afraid, especially during gunnery missions, [illegible] not concentrate on [illegible] e and [illegible] which [illegible] to be [illegible] child [illegible] older, writing for instance. In the plane the pilot had to look for his wedding ring in order to identify left and right when he got instructions over the radio to bank the aircraft. This delay of reactions seemed to explain why he did not like close formation and why he always *had to be careful*. He had a tendency to stutter and to mix letters in his writing, symptoms which often follow handedness problems

This pilot was grounded for 2 months During this period he recovered from his psychosomatic symptoms and felt happy. He was then transferred to a communication wing where he has adjusted himself successfully during these past 6 months.

Case 2

An 18 year old cadet at the flying school did not make the desired progress He was "below average" as regards flying, and in the class he seemed to be absent-minded and careless. His behaviour was so peculiar that he was regarded as "nuts" by his supervisors. He seemed to be socially isolated and lacking initiative in all aspects.

[illegible]

A certain dullness was reported, however.

This cadet was dominantly left-handed, despite writing and drawing with his right hand He withdrew from flying training at his own request when he was told that he did not adjust successfully to the training programme.

Case 3

A captain, leader of a fighter squadron, suffered from muscular fatigue and pain in the right arm and shoulder and in his back. In the plane he was forced to use his left hand on the rudder bar in order to relax his right arm

He was away from duty a month or more at a time and received physiotherapy for several years without any lasting effect. The illness began and developed during his flying career.

During our interview with him he stated that of all planes he preferred the twin engined Anson where he in the left seat usually handled the wheel with his left arm when he could not use both. While in the fighter squadron he envied the pilots flying the Dakotas, but he never applied for transfer through fear of being called "yellow". He has been transferred from fighter squadron to the High Command because of his illness. This captain is left-handed but writes and draws with his right hand

Case 4

One fighter pilot, a second lieutenant, 22 years old, was grounded because of "dangerous tendencies" in the air. He was characterized as "peculiar" by [illegible]

[illegible] drawing with the left. He has obviously learned to use the right hand in a great many situations.

Case 5

A lieutenant, 25 years old, flying as a second pilot in a Dakota, was grounded because of flying deficiency. One year before he had been transferred from a fighter to a transport squadron upon his own request.

About one month [illegible]

Th [illegible]

[illegible]

wa [illegible]

most situations

Case 6

A 23 year old fighter pilot made a crash landing about 2000 ft from the runway because of "flame out". It was found that he had run out of fuel although he had been flying near the air base for a long time At one time he

had reported a fuel level of 900 lb and a few minutes afterwards he reported 1370 lb ...

... The last instrument does not as a rule give readings corresponding to the fuel level indicated by the first mentioned instrument. The pilot had observed the "fuel pressure warning light" and he checked the fuel level again but probably on the wrong instrument, and he did not react as in emergency because he thought that the red signal had appeared because of electrical "snags."

This pilot had been fairly well adjusted to flying before this accident and was on the point of being selected as a "deputy flight commander."

The pilot is left-handed, writing with his right hand.

Before we had seen those cases, the writer had already for some time had the impression that the term "left-handedness" was rather inadequate as a scientific term. It might tend to hide a lot of the phenomena usually accompanying left-handedness and make our considerations unfruitful concerning a topic which might turn out to be vital in an air force where the aircraft is to be manipulated ... that the ve... had been o... hand, such capacities and abilities that were of great importance earlier would now turn out to be unimportant, or even disadvantageous.

We had in our minds an impression that left-handedness was very often followed by a marked slowing up of thought and reaction, and that a rather short delay would have a much greater effect on the pilot performance today than, say, 10 years ago

In the following we will try to discuss our problem in a little more detail

The Concept

In the literature, handedness is usually thought of and handled as the primary subject, other phenomena being linked up with it in a secondary, subordinate manner. ...

We usually get the impression that handedness tells us which hemisphere is the dominant one. Left-handedness means a dominant right hemisphere. Our first doubts regarding this view arose as we observed in the literature that there was also something called eyedness, and that no certain connection could be established between eyedness and handedness. How could that be so? If one hemisphere is dominant, that ought to mean that every performance in that part should dominate our behaviour. However, there is the fact that the process of seeing involves both motor and sensory components—where the motor component is not only confined to oculo-motor action, as postural muscles of the neck are also involved. In testing for eyedness we can eliminate muscular action other than the oculo-motor, but still many possibilities remain. Imagine a right dominant hemisphere. The left half of each retina, then, should be the most "alert" one, that is, to the stimuli entering the eye from right

However, we don't like stimulation from the side, so we turn our head and eyes so as to get the rays in the fovea, a little temporal in each eye. As a consequence, in central (cone) vision, impulses are transmitted to both hemispheres. Eyedness is, however, the habit of using one eye and allowing the other to remain "inactive". The possibility remains then that visual hemisphere dominance (laterality) has nothing to do with eyedness.

As to the oculo-motor innervation, we may say that fixation of an object among other things means convergence of the eyes. The inner muscles contract after innervation from the respective hemispheres. There will be a rivalry, and the stronger muscle wins, to the effect that the opposite eye is kept "inactive". But there is also another possibility. In order to avoid [illegible]

bining the components in visual and motor habit formation, and that research on the topic will have to be correspondingly complex and elaborate.

It seems usual to conceive dominance as a unitary mastery of one hemisphere, but this it can be questioned, as seen in this quotation (HILDRETH 1949, p. 259)

> "According to ORTON (1937), it is only in man that this cerebral dominance is shown, and in man only in language and more intricate manual skills in which this specialization occurs In these activities the two hemispheres can function quite independently of each other Observations of clinical cases show that in people without established hand dominance the language mechanism is also unlateralized in the cerebrum (CHESHER, 1936). Actually the only guide to indicate which is the dominant hemisphere is the laterality of the individual exhibited in his sidedness and disturbances of function in aphasia and brain lesion cases. Even this evidence gives conflicting results. Complete cortical dominance has not been proved. The left-hemisphere in right-handed persons cannot be considered 'dominant' for all nervous functions".

If we could isolate different functions in our laterality research, we could reach a conclusion about this problem. For instance, one could claim that different cortical areas might as well have a laterality fixed independently of the other ones. As a consequence we might come to see a *laterality pattern*, variations in which would be one of the reasons for individual differences in behaviouristic and perceptory tendencies It would also be pertinent to the problem of individual differences in learning certain activities.

FUNCTIONAL FIELDS

In order to get a survey of our problems we would like to distinguish different functional fields. Such fields cannot, of course, be clearcut and unitary.

Our problem is primarily a problem of direction or space· Which direction is the dominant one? Right or left? Handedness is the most conspicuous

aspect in directional behaviour, and has, therefore, been more mentioned than any other aspect. We will try to consider the different functions to find out if and how they show directional or spatial trends. Because of the primary role of spatial factors in the pilot's job, our considerations will be important in that connection, whatever might be their theoretical implications.

Motor functions: handedness

We usually talk about handedness to state that there exists a preference to use one hand (and leg) in activities where hand (leg) activity is involved. Dextrality means preference of the right hand, as opposed to sinistrality, which means preference of the left hand. When no hand is preferred, the individual is said to be ambidextrous. As mentioned previously different phenomena are believed to accompany left-handedness. When the individual is right-handed those things are thought to be caused by something different from laterality (or brain dominance).

The left-handed individual is exposed to a continual problem of adjusting his movements to those of the environment. When he is a pilot, he has to manipulate a stick and a dash board which human engineering has given the ideal design—for the right-handed pilot. So he has to do a lot of motor learning to manage his job.

If this is his only problem, it is not detrimental. There are left-handed pilots who do not experience any trouble And there are a lot of right-handed pilots who are enormously troubled in their attempts to learn to fly. We have, however, seen that left-handedness is frequently accompanied by a tendency to reverse movements, speech and thought. This is detrimental, and we believe that such a tendency to reverse is basic and "incurable". A person may learn to write "g" and "d", but when he, in fluent use of the two letters, has a marked tendency to use them in an opposite manner, he is also due to make other movements in an opposite manner. He may learn to use the right letter in the right place, if he is allowed to hesitate a little before forming the letter But when he is in a hurry, he will inevitably make the wrong movement at one time or another As a pilot, with a stick in his hand instead of a pencil, he may be apt to make a dive when he intends to climb, and he may make a right turn when he ought to make a left one. *The possible consequences are clear if the aircraft is near the ground or in a formation.*

As a consequence of this steady tendency to reverse, the persons concerned [illegible] ...rformance (Case 1) [illegible]

[illegible] they reach the crucial point (for instance in firing at the target)—in other words as long as they do not know what is coming next. If such is the case, *we will be interested in screening out such persons* at an early stage. We will have to look for details in the applicant's behaviour during selection. We will have to make close observations of the pilots in their duty performance, and we will have to look for such behaviour in accidents and near accidents.

Sensory functions: vision

As mentioned, eyedness may be related to different steps in the act of seeing. It may be a motor habit and as such be subject to motor learning

As there is no close connection between handedness and eyedness, the way to use one's eyes may have been established through mere chance—a possibility we cannot exclude. That would not be any problem beyond the problem of changing the habit through training. But we still have to account for directional tendencies in our perception of movement and spatial relations. Several persons are peculiar in that they have a fixed tendency to reverse or to be uncertain about right and left.

They have a tendency to read "d" instead of "b", "14" instead of "41", etc. The problem is to determine where in the process the reversal is made. In the above mentioned examples we will see that "d" and "b" are reversed—mirrored—pictures which cannot be due to mirrored movement in the speech organ. Therefore it would be appropriate to ascribe it to the visual centre. The other example, however, is a figure consisting of two parts, "1" and "4", whose sequence has been changed and is, then, a less revealing symptom. A pilot who has a tendency to see things backwards is likely to act in an opposite manner. If that is his only deficiency, i.e. if he has not the habit to reverse movements at the same time, he will react directly on an opposite figure. If he also tends to revert movement, his reaction will be *more uncertain about the direction. In copying a number, for instance 23,* he may always be uncertain about the result because he does not know what he has done. He may read it correctly and write it backwards. He may read it backwards and write it backwards (result correct), etc. If we ask the person to say the number before writing it, we get the following possibilities

Read	*Speak*	*Write*
23	23	23
23	23	32
23	32	23
23	32	32
32	23	23
32	23	32
32	32	23
32	32	32

That means statistically about 50 per cent chance of doing it wrong. A telephone number with 6 ciphers is almost an impossibility unless the number is read and reproduced digit by digit.

Practically it will be important to single out the individuals with such tendencies because of the demand that they shall read instruments correctly.

Perceptory functions: form and space

According to an analysis made by GIBSON (1950, p. 53) a typical retinal image contains "two fundamental types of stimulus variation, one in the character of the focused light at any point and another in the relation of these light-points to one another". This image is a projected arrangement of light, not a "picture", and may be said to be a basic correlate of visual perception. For our purposes the percept may be said to have formal and spatial qualities.

the retina, will all reduce visual acuity. Stereoscopic acuity (in binocular vision) is assumed to be of overwhelming importance to the pilot's ability to operate in the air. That is a belief which can be questioned, for several reasons, as mentioned by GIBSON (1950, p. 108):

> "... persons having vision in only one eye, or temporarily limited to use of one eye, see the visual world in depth just about as much as the rest of us do and get about in it without conspicuous loss in efficiency. There have even been one-eyed fliers, of whom Wiley Post was the most notable."

Can perception of form be impaired by laterality? Probably yes. Spatial comprehension is a very important aspect, and is conspicuous in art comprehension, as mentioned by GAFFRON (1950, p. 329) in the following statement:

> "A prevalent role of visual space perception might explain why the glance-curve is confined to the culture of the Western world, beginning with the Greek. Its connection with brain dominance would explain why it is not found in young children. Furthermore, according to this theory, a left-handed person with a completely reversed brain dominance (which is an exception, and not the rule as is generally believed) should have a [illegible] he world as a mirror- [illegible] of art is furnished by [illegible] but also most of his pictures, have to be reversed in order to show the composition which best fits the subject matter from the point of view of the spectator. (With the exception of the direction of light (determined by the actual position of the window) the mirror-image of the famous last Supper furnishes a convincing example, especially for laymen who are not too well acquainted with the original). The problem of reversal is most important in the graphic arts, since prints are the mirror-images of the drawings on the plates."

("What is sinister about sinistrality"? WILE (1932, p. 44) asks. He mentions a lot of prejudices as regards left-handedness. But may be the answer is to be found in the normal individual's reaction to the strange way in which the left-handed see and do things).

An important statement has to be made in this matter. The phenomena [illegible]

to meet the intentions of other individuals. He would perceive a square, a house, a tree and the like with the same ease as others. But when these elements are part of artificial constructs reflecting the mental processes of others, he may be afflicted. My comprehension of a product is facilitated if the pro- [illegible]

may conclude, then, that a pilot may be proficient in spatial behaviour *per* [illegible]

[illegible] perception. It deserves special mention. GOLDSTEIN (1948, p. 99) in treating brain injuries mentions how he uses tachistoscopic examination

> "For a quick survey of mental capacities, tachistoscopic examination is of great value. Sometimes the main defects will be revealed in one examination. Of course each defect revealed in this way should be studied in detail. However, results obtained with the tachistoscope will prove a very useful guide in our procedure. Tachistoscopic examination should be a part of the routine investigation The principle of this examination is to expose some figures and other objects for a short time (1/5 or 1/10 sec) and have a subject report what he has seen
>
> Many disturbances which are not discovered in the ordinary examination come to light when the perception time is shortened in this way."

One might believe that differences between normal individuals will be discovered much earlier in this way, and that we have the possibility to differentiate in a more minute manner than is usual in paper and pencil tests. This will be an important field of investigation when we want to take in account factors influencing pilot proficiency.

Perceptory functions ideation

Some years ago the writer read a composition where the two words "exogen" and "endogen" were used consistently in the opposite meaning. The author's handwriting was characterized by many spasms and corrections [illegible]

"Topf".

In German "Topf" is, then, the same as "pot" in English. Another example is found in the words "boat" and "tub", which have much the identical meaning, the "tub" being, however, a "not-so-good-boat". (We do not know exactly if "tub" is a reversal of "boat", but it seems reasonable, as the vowels are of minor importance in the word structure, and has often been omitted in ancient languages.) Another case is seen in the Latin words. "ALtitudo" and "LAtitudo", which we have only noticed as a peculiarity.

It is interesting to note that some persons have a constant tendency to distort words in this way, especially at the first occurrence of the word. By

the second saying it may be corrected, sometimes even during the first saying. The following series of observations shows this. They were all observed in a girl, now *5 years old:*

Age	*Pronounced word*	*Correct word*	*Notes*
1·6	påke	kåpe	
1·6	koss	sokk	
1 6	pusse	suppe	
1 6	flöyse	sloyfe	
3·7	lusemort	muselort	
3 7	flotthass	flosshatt	
3 7	danke dusen	danse dukken	Discovered the fault while saying it.
3 7	parsıman	marsıpan	Did not discover the fault herself. Now corrected.
3 10	gormanisse	organisme	
3 11	jattnakke	nattjakke	
3·11	Doland	Donald	Persistent Not corrected as yet.
4 6	regle nensene	rense neglene	
4·7	magasjebukse	gamasjebukse	
4 9	Chikasjan	Chinasjakk	
4·9	Jente huletreet	Hente juletreet	Discovered while saying it.

This girl shows a fairly good verbal fluency most of the time. But sometimes she stops at a word, repeating it several times because she does not know which word to use next. She cannot reproduce it. She also has a tendency to put the words in a rather complex sequence which equals the German syntax. She may for instance say "Yesterday I have been in town, and I have bought a doll." Another peculiarity is the tendency to answer "No" when she ought to say "Yes", and vice versa. It seems to be a matter of which entity she chooses to react upon.

Example "Shan't we go in the shop?" Answer "No"—which means: "I don't agree in that statement, because I wish to go with you in the shop." As far as we know the same type of answers is usually found in Chinese.

The girl is not left-handed, but she had a comparatively long period before her right-handedness became fixed. (Unfortunately the time has not been recorded.)

It will be understood that such tendencies to reverse or change ideas must be of some importance. However, they are difficult to study because they are to a great extent eliminated from speech through learning, and we are unable to observe the rudimentary tendency We cannot exclude the possibility that a reversed ideation may occur in a never-before-experienced situation, which is a dangerous event in flying. Case 6 seems to concern this type of cause. The pilot ought to recognize that fuel volume is reduced during flight Maybe this case can be compared with an example mentioned by HERMAN (1955, p. 125).

"If a word-blind person reads the words "egn" (region) and "eng" (meadow), he seems to be rather helpless if he, after a long period, says that "the word 'eng' is written twice, but is spelled differently each time".

Conclusion

analyses in order to find the weak point (or points) in the chain. Some phenomena will probably occur together more often than others. Handedness is not a very rare phenomenon but we would rather stress the importance of direction Left-handedness without directional aberrations does not create the sort of problem we have treated. Directional aberrations without left-handedness have a greater chance to be neglected.

Sommaire

l'hémisphère droit, et s'accompagne de déficiences secondaires dans la lecture, le langage, la coordination motrice, etc.. Mais ce concept doit être révisé. Pourquoi, par exemple, chez les gauchers, l'oeil directeur n'est-il pas soumis à la prédominance droite, qu'il s'agisse de fixation ou de convergence (musculature extrinsèque et intrinsèque)? En réalité, les localisations permettant d'affirmer la prédominance d'un hémisphere ne se trouvent que dans l'aphasie et certaines lésions cérébrales. La prédominance corticale complète n'a jamais été prouvée. Chez les droitiers, l'hémisphere gauche ne peut être considéré comme "dominant" pour toutes les fonctions nerveuses. On doit penser que seules certaines fonctions sont latéralisées, en raison de différences individuelles de comportement et de perception En ce qui concerne le pilote, on doit considérer surtout

Les fonctions motrices (droitiers, gauchers, ambidextres)—Les commandes étant établies pour le droitier, le gaucher doit faire l'apprentissage de sa motricité Certains y parviennent très bien Mais la gaucherie s'accompagne souvent d'une tendance à inverser les mouvements, le langage et la pensée. Cette tendance est essentielle et incurable Compatible avec la vie courante, elle est inadmissible chez le pilote appelé à exécuter des mouvements rapides et précis. Certains de ces pilotes deviennent d'une prudence et d'une lenteur excessives

Les fonctions sensorielles: vision—Il n'y a pas de rapport entre la gaucherie et l'oeil directeur celui-ci dépend de tendances directionnelles dans la perception des relations cinétiques et spatiales, et quelques sujets ont une tendance permanente a inverser, à lire par exemple d *au lieu de* b, 14 *au lieu de* 41, *etc. . . . Un pilote qui a tendance à voir à l'envers est également exposé à agir à l'envers*

Les fonctions perceptives forme et espace—Un pilote doit avoir une vision nette

ment dans certaines directions, de prendre sa place dans une formation, etc. . . . c'est-à-dire là où intervient la rapidité de la perception. L'examen tachystoscopique est alors de grande valeur (observations 1 et 6).

the second saying it may be corrected, sometimes ...

Age	*Pronounced word*	*Correct word*	*Notes*
1·6	påke	kåpe	
1·6	koss	sokk	
1·6	pusse	suppe	
1·6	floyse	sloyfe	
3·7	lusemort	muselort	
3·7	flotthass	flosshatt	
3·7	danke dusen	danse dukken	Discovered the fault while saying it.
3·7	parsıman	marsipan	Did not discover the fault herself. Now corrected.
3·10	gormanisse	organisme	
3·11	jattnakke	nattjakke	
3·11	Doland	Donald	*Persistent. Not corrected as yet.*
4·6	regle nensene	rense neglene	
4·7	magasjebukse	gamasjebukse	
4·9	Chikasjan	Chinasjakk	
4·9	Jente huletreet	Hente juletreet	Discovered while saying it.

This girl shows a fairly good verbal fluency most of the time But sometimes she stops at a word, repeating it several times because she does not know which word to use next. She cannot reproduce it. She also has a tendency to put the words in a rather complex sequence which equals the German syntax. She may for instance say· "Yesterday I have been in town, and I have bought a doll." Another peculiarity is the tendency to answer "No" when she ought to say "Yes", and vice versa. It seems to be a matter of which entity she chooses to react upon.

Example: "Shan't we go in the shop?" Answer: "No"—which means: "I don't agree in that statement, because I wish to go with you in the shop."

recorded.)

It will be understood that such tendencies to reverse or change ideas must be of some importance. However, they are difficult to study because they are to a great extent eliminated from speech through learning, and we are unable

The pilot ought to recognize that fuel volume is reduced during flight. Maybe this case can be compared with an example mentioned by HERMAN (1955, p. 125).

"If a word-blind person reads the words "egn" (region) and "eng" (meadow), he seems to be rather helpless if he, after a long period, says that "the word 'eng' is written twice, but is spelled differently each time".

Conclusion

It will be seen from the above treatment that tendencies of reversing or uncertainty in directional behaviour may be of great interest when we want to know something about flying proficiency. We will have to make thorough analyses in order to find the weak point (or points) in the chain. Some phenomena will probably occur together more often than others. Handedness is not a very rare phenomenon but we would rather stress the importance of direction. Left-handedness without directional aberrations does not create the sort of problem we have treated. Directional aberrations without left-handedness have a greater chance to be neglected.

Sommaire

L'auteur rapporte six observations de pilotes dont l'inadaptation aux exigences du vol semble avoir été en rapport avec le fait qu'ils étaient gauchers.

On admet généralement que la "gaucherie" correspond à une prédominance de l'hémisphère droit, et s'accompagne de déficiences secondaires dans la lecture, le langage, la coordination motrice, etc. . . . Mais ce concept doit être révisé Pourquoi, par exemple, chez les gauchers, l'oeil directeur n'est-il pas soumis à la prédominance droite, qu'il s'agisse de fixation ou de convergence (musculature extrinsèque et intrinsèque)? En réalité, les localisations permettant d'affirmer la prédominance d'un hémisphere ne se trouvent que dans l'aphasie et certaines lésions cérébrales La prédominance corticale complète n'a jamais été prouvée Chez les droitiers, l'hémisphere gauche ne peut être considéré comme "dominant" pour toutes les fonctions nerveuses. On doit penser que seules certaines fonctions sont latéralisées, en raison de différences individuelles de comportement et de perception En ce qui concerne le pilote, on doit considérer surtout

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Les fonctions perceptives forme et espace—Un pilote doit avoir une vision nette qui dépend non seulement de son accommodation, mais d'autres conditions internes et externes (lésions de la région occipitale, des voies optiques, de la rétine) L'acuité stéréoscopique est essentielle, mais non indispensable (cas des pilotes borgnes). Un pilote peut avoir une vision correcte de l'espace "en soi", mais être déficient quand il se trouve en face d'intentions d'autres individus, comme l'ordre d'exécuter un mouvement dans certaines directions, de prendre sa place dans une formation, etc. . . c'est-à-dire là où intervient la rapidité de la perception. L'examen tachystoscopique est alors de grande valeur (observations 1 *et* 6*).*

the second saying it may be corrected, sometimes even during the first saying. The following series of observations shows this. They were all observed in a girl, now 5 years old:

Age	*Pronounced word*	*Correct word*	*Notes*
1·6	påke	kåpe	
1·6	koss	sokk	
1 6	pusse	suppe	
1·6	floyse	sloyfe	
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Example: "Shan't we go in the shop?" Answer· "No"—which means: "I [illegible]

recorded.)

It will be understood that such tendencies to reverse or change ideas must be of some importance. However, they are difficult to study because they are to a great extent eliminated from speech through learning, and we are unable to observe the rudimentary tendency. We cannot exclude the possibility that a reversed ideation may occur in a never-before-experienced situation, which [illegible] Case 6 seems to concern this type of cause. [illegible]

(1955, p. 125).

"If a word-blind person reads the words "egn" (region) and "eng" (meadow), he seems to be rather helpless if he, after a long period, says that "the word 'eng' is written twice, but is spelled differently each time".

TRAINING PERFORMANCE AS A SELECTION DEVICE

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THIS is a report on our efforts in "secondary screening" which is becoming a vital part of our present selection programme. Our researchers at Pensacola, of course, continue their efforts toward sharpening our present selection devices; which include reassessment of the changing requirements of aviation training, continuous cross-validation of our current tests, the trial of new aptitude tests, and developmental work in the area of motivational testing. More recently, however, we have placed increased emphasis in the area of "secondary screening".

By secondary screening we mean the utilization of the measurements of our selection procedures beyond the initial examination and screening stage. That is, the use of measurements of individual differences as predicators of [illegible]

with a limited manpower pool

We interpret these rather unpleasant facts to mean that the improvement of selection predictors cannot come about by increasing our screening elimination rate It must come about by some additional measures. We further felt that in our current state of knowledge the addition of more aptitude or motivational tests was not the answer. To escape from this dilemma we fell back on an old selection adage Extensive on-the-job measures are typically good predictors of future on-the-job performance

The first step was to turn to the pre-flight period of the Naval Air Training Programme. This is a 16-week period in which the cadets are indoctrinated, given physical and military training, and course work in navigation, aerology, engines and principles of flight. Very simply the measures of perforance in these areas were combined into a correlation matrix with our selection tests, and validated against two criteria success–failure and overall performance throughout the programme. Multiple regression equations were derived for the two criteria A compromise weighting of the scores was developed and the four best measures were placed in a formula. The pre-flight progress grade was the consequence In detail we found that the Mechanical Comprehension Test from our selection battery, navigation scores from the academic side of pre-flight, physical training grades, and Officer-like Quality grades were the most useful scores.

In validation and cross-validation of this grade remarkably accurate predictions were possible in regard to progress in the primary stages of flight training validity coefficients of around 0·5 were consistently obtained.

The next step was to implement the use of this score. We recognized that although we had improved our predictions we were still not completely

Idéation—La tendence à inverser ou à changer les idées, qui s'observe aussi bien chez certains droitiers, peut se manifester dans une situation nouvelle et inattendue (observation 6).

En conclusion, la tendance à inverser ou l'incertitude dans le comportement directionnel peuvent présenter beaucoup d'intérêt quand nous voulons étudier l'aptitude au pilotage. Nous devrons faire des analyses complètes pour trouver le ou les points faibles de la chaîne. Certains phénomènes se produiront probablement et simultanément plus souvent que d'autres. La gaucherie n'est pas un phénomène très rare mais il faut souligner surtout l'importance de la direction. La gaucherie sans aberrations de direction ne pose pas le genre de problème qui a été traité ici. Les aberrations de direction sans gaucherie risquent davantage de passer inaperçues.

References

Fagan, L. B. "Graphic Stuttering". *Psychol. Monogr.* **43,** No. 14, 67–71, 1932.

Gaffron, M. "Right and Left in Pictures". *The Art Quarterly* **13,** No. 4, 312–331, 1950.

Gibson, J. J. *The Perception of the Visual World.* Houghton Mifflin, New York, 1950.

Goldstein, K. Aftereffects of Brain Injuries in War. New York: Grune & Stratton, 1948.

Herman, K. "Om medfødt ordblindhet" *(On Congenital Word Blindness)* Copenhagen: Munksgaard, 1955.

Hildreth, G. "The Development of Hand Dominance", I–V. *J. gen. Psychol.* **75,** I: pp. 197–220, II: pp 221–254, III: pp 255–276, **76;** IV: pp 39–100, V: pp 101–144, 1949.

Wile, I. S. "The Relation of Left-handedness to Behavior Disorders". *Amer. J. Orthopsychiat.* **2,** 44–57, 1932.

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By secondary screening we mean the utilization of the measurements of our selection procedures beyond the initial examination and screening stage. That is, the use of measurements of individual differences as predicators of proficiency throughout the total span of training.

That programme was and is based on two realistic facts (I) Selection is at present far from perfect, and (II) peacetime training typically operates with a limited manpower pool

We interpret these rather unpleasant facts to mean that the improvement of selection predictors cannot come about by increasing our screening elimination rate. It must come about by some additional measures We further felt that in our current state of knowledge the addition of more aptitude or motivational tests was not the answer. To escape from this dilemma we fell back on an old selection adage Extensive on-the-job measures are typically good predictors of future on-the-job performance

The first step was to turn to the pre-flight period of the Naval Air Training Programme. This is a 16-week period in which the cadets are indoctrinated, given physical and military training, and course work in navigation, aerology, engines and principles of flight. Very simply the measures of performance in these areas were combined into a correlation matrix with our selection tests, and validated against two criteria success–failure and overall performance throughout the programme. Multiple regression equations were derived for the two criteria A compromise weighting of the scores was developed and the four best measures were placed in a formula The pre-flight progress grade was the consequence. In detail we found that the Mechanical Comprehension Test from our selection battery, navigation scores from the academic side of pre-flight, physical training grades, and Officer-like Quality grades were the most useful scores.

In validation and cross-validation of this grade remarkably accurate predictions were possible in regard to progress in the primary stages of flight training validity coefficients of around 0 5 were consistently obtained.

The next step was to implement the use of this score. We recognized that though we had improved our predictions we were still not completely

accurate and could not afford a wastage of manpower. We therefore restrained ourselves from recommending an elimination of individuals at this point and developed a procedure of "tagging" trainees. That is, grades were calculated on all men; however, these grades were not widely disseminated but were given only to disposition boards. These disposition boards are convened when a student has demonstrated sufficient inadequacies in training to require a decision as to his continuation in the programme or not.

It was (and is) our recommendation that these scores be used as sources of information to determine whether a student should be permitted to continue *after* he has displayed inadequate performance.

We feel that this procedure of tagging has a number of advantages: (I) We do not increase the losses from the programme of those individuals who we say are inadequate but who could succeed. These men who display no difficulty are unaffected by our inaccurate predictions. (II) Potentially capable men (those with high progress grades) can be given additional training time more freely. (III) Potentially inadequate men (those with low progress grades) are judged more specifically on variables which have in the past been most predictive. We noted that disposition boards frequently used past records but the weighting of various factors differed radically between board members. Typically, for example, our selection tests were considerably "over weighted" in these decisions.

The efficiency of the pre-flight progress grade as a predictor of future training difficulties is attested to by the figures given in *Table I*.

Table 1 Relationship Between Pre-Flight Progress Grades and Students Having S.P.D.B. Meetings During Primary Flight (P F P G) Training

	Satisfactory P.F.P.G.		Unsatisfactory P.F.P.G	
	Number	*Per cent*	*Number*	*Per cent*
S P D B	128	12	64	80
No S P D B	897	88	16	20
Total	1025	100	80	100

The computation of pre-flight progress grades on all students graduating from pre-flight was begun in February 1955. In July 1955 data was obtained from the primary training field on the 1105 students who had completed or were undergoing primary training at that time. Previous calculations had set the definition of an unsatisfactory progress grade at approximalely 7½ per cent as a critical cutting score. Data was obtained to determine the number of students who had experienced severe enough training difficulties to appear before a student pilot disposition board (S.P.D.B.) during the period of time under study. These data divided into satisfactory and unsatisfactory progress grade groups are presented in *Table I*. Simply enough these figures indicate that while only 12 per cent of the students with satisfactory progress grades had appeared before a student pilot disposition board, 80 per cent of the students with unsatisfactory progress grades had by that time

appeared before student pilot disposition boards. Furthermore, when it is recognized that a large number of the students in this study had probably had only a limited opportunity to display their inadequacies by the time the data was collected, and therefore that it would be likely that the trends obtained in *Table I* would be accentuated, the figures of *Table I* show dramatic accuracy of prediction for the progress grade in relation to future flight performance.

Because of the success of this procedure to date and its eminent sensibility we have been requested to develop this grade for advanced training, based on progress up to that point. This is now in process. There is some evidence that this activity will be a co-ordinate of our effort in classification, i.e. the assignment to type in advanced training programmes.

We will admit the self-validating quality of this procedure as it becomes fully operative. The men with low progress grades who get into trouble will tend to be summarily eliminated, those with high progress grades will be given additional chances. Scientifically, this may be described as contamination. Operationally, however, we view this fact favourably. The information that we are feeding into disposition boards describes the performance of thousands of men who have been previously trained in the programme. We feel that this is valid information for disposition boards to use in their deliberations. To briefly summarize. By combining our selection grades with measures obtained from training performance we were able to furnish training personnel with highly predictive scores in progressive stages of training. These are presently utilized in a "tagging" procedure which permits the individual candidate to "validate" our predictions concerning him. This does not increase attrition by eliminating men on whom our predictions may be incorrect as a pure secondary screening procedure would operate. It further furnishes decision-making boards the wisdom of a large number of cumulated previous experiences. It is interesting to speculate on the potentiality of such a tagging procedure at the initial screening level as we realistically face the problems of increasing restriction in procurement

Sommaire

L'Ecole de medecine aéronautique de la Marine à pensacola, tout en continuant à améliorer ses méthodes de sélection initiale, attache une importance croissante à ce qu'elle appelle le "criblage secondaire" (secondary screening), et qui consiste dans la prolongation des mesures de sélection au-delà de la periode d'examen d'aptitude a l'entrée

Étant donné l'imperfection de la sélection initiale dans son état actuel, et les faibles effectifs du temps de paix, il ne peut être question d'augmenter le taux des éliminations, il faut recourir à des mesures supplémentaires en appliquant le vieux diction que "c'est à l'oeuvre qu'on juge l'artisan".

Pendant la periode de "preflight" (au sol) qui dure 16 semaines, les résultats obtenus par l'élève sont mis en corrélation avec des tests de sélection tels que le test de compréhension mécanique, les notes de navigation théorique, de culture physique et l'aptitude au commandement—avec des coefficients de validité de (0·5). Dans un deuxième temps, les élèves ayant manifesté des insuffisances notables sont convoqués devant un "disposition board" qui opère une sorte de repêchage et décide s'il y a

lieu de leur faire continuer l'entraînement. Cette procédure permet de conserver des sujets pour lesquels la sélection initiale s'est révélée inexacte, de pousser les sujets vraiment capables, et de juger les insuffisants de façon plus approfondie.

Le succès de cette procédure a été tel qu'elle sera incessamment étendue aux stades ultérieurs de l'instruction (advanced training).

THE SIGNIFICANCE OF THE ABNORMAL ELECTROENCEPHALOGRAM IN AIRCREW

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There are two main types of abnormality to be seen in the EEG, the constitutional or inborn, and the acquired The acquired abnormalities occur under circumstances ranging from the distinctive lesions of injury, infection and tumour to those associated with general biochemical disorders and with alterations in levels of consciousness It is not the present purpose to discuss these latter

The constitutionally abnormal EEG does not mean that a subject has already shown symptoms of abnormal behaviour but that, if he has not done so he is either more likely to do so than one of his fellows, or he may transmit the tendency to his offspring

The constitutional abnormalities may be (I) non-specific, such as may be found in epileptics, psychotics, psychopaths and other subjects of behaviour disorder or in their relatives, and (II) specifically epileptic.

A specifically epileptic disturbance, i e. a larval attack, may appear in an otherwise normal record or in an abnormal record, but in at least a quarter of all abnormal records of epileptics larval attacks are not seen. This is because of the limited time spent in recording, since every classical fit is accompanied by characteristic change in the EEG and this must eventually be seen. Constitutional abnormalities are usually fixed, but may alter and even disappear with maturation and ageing The acquired abnormalities are frequently transient but especially where permanent pathological changes may be expected to have occurred they may have permanent abnormal sequelae

Although there is a wide range of EEG patterns found in people who seem to be normal, we are slowly learning that some of the deviations from the average which are seen have a reflection on the individual's response to [illegible]

cent of a sample of 309 aircrew candidates with an average age of 20½ showed records which they recognized as immature but which by applying strict adult standards would have been characterized as abnormal. It is important also to remember, as Pond has shown, that maturation does not take place in a smooth curve but shows steps and is subject to delay and unequal progress

In the RAF clinic as in most other major ones this factor has been realized [illegible]

In spite of many studies of the normal population, there is little evidence that the meaning of abnormal features found in the EEG of normal people has been closely examined. We know, however, that the abnormalities can be related to minor physical and psychological disturbances—disturbances which become more apparent under the physical and psychological stresses of high performance flying.

Some of the conclusions we can draw will be discussed in relation to the problem of the use of the EEG in selection, and our findings in relation to episodes of unconsciousness in the air will be briefly mentioned.

I shall not here discuss the results of special methods of activation such as Flicker, Sleep and Metrazol. I personally have found these only of minimal use in clinical medicine and then only in selected cases, a view which is supported by MUNDY-CASTLE (1953) who finds only about 3 per cent of abnormal response in a control population, and by SCHWAMB *et al.* (1956) of the U.S Army who find by controlled experiment that the results of metrazol activation are not significant in a normal population. But my main reason for rejecting them for routine use is that they make high demand on skilled personnel for their application and interpretation and therefore are primarily of research use. Any procedure which is normally of use for military selection must be able to be applied rapidly and to make very small demands on high trained staff. In the RAF, for instant, at the peak of the war we had 150,000 aircrew and no highly specialized examination could have been applied to them.

POSSIBLE USES OF THE ABNORMAL EEG IN AIRCREW WITH REGARD TO SELECTION AND PERFORMANCE

It is important at the outset to take a balanced view. The generally accepted figure for EEG abnormalities in a control population is 10–15 per cent. Training losses are usually quoted at from 30–50 per cent so that even if all possessors of abnormal records were unsuccessful for aircrew duties (and we know they are not) the EEG would only reject a minor proportion of failures and under existing techniques we are without individual information in 9 out of 10 persons examined.

Reviewing what information we have: PICARD *et al.* (1955) state that controlled experiments have shown that the best pilots are those who have the most normal trace. On the other hand GREY WALTER (1955) has suggestive evidence, which he hopes to confirm, that certain specific mild abnormalities are uniformly found in successful Fleet Air Arm pilots.

On a more positive level WILLIAMS (1941) has shown that whereas there were 10 per cent of abnormal records in a sample military population, only 5 per cent of aircrew at the conclusion of training had an abnormal EEG. The samples, however, were small and the difference between the two groups is not statistically significant ($\chi^2 < 2$), although his findings may nevertheless be true and might be shown to be so if carried out on a larger scale.

More recently BUCHTHAL and LENNOX (1953) have investigated a population of aircrew candidates. They divided their findings into several grades of abnormality and on these gradings considered that nearly 20 per cent of the records taken under standard conditions were not normal. They found

to be of any statistical value in selecting those who can learn to fly on an aptitude basis. I say this not to decry the use of the normal EEG but to suggest that much more work needs to be done to see whether our clinical judgment is, in fact, correct.

It is possible of course that such temperamental defects as we know are associated with abnormal EEG's are in the main not those connected with

In more specialized connexion we can say that of a general population it

1 in 40, or twice that of any unselected person at birth.

Fifteen per 1000 aircrew per year are referred to the psychiatrist. ROOK (1947) working with WILLIAMS, found that 13 per cent of neurotic aircrews showed abnormal records so that the chance of aircrew having an abnormal EEG and of developing a neurosis in any one year is about 1 in 500.

To summarize therefore our knowledge of the abnormal routine EEG we can forecast that if all aircrew with abnormal records were rejected, the EEG has no definite chance of rejecting failures to learn to fly and a 1 in 50 chance of rejecting neurotics at a 10 per cent rejection level, and a 1 in 40 chance of rejecting epileptics at a 2 per cent rejection level. All of which are, in my view quite uneconomical and ignore the part already played by other means of selection

There is, however, another side to the abnormal EEG to be considered, and that is the quality of performance of its possessors We know from the work of REID and RUSSELL DAVIS that the anxiety prone individual is less efficient as an aircrew member than the average. REID (1947) assessed by a standard form of RAF psychiatric interview the personnel of bomber

used by REID He showed that whereas 1 in 18 5 normal reactors to his tests failed to learn to fly, 1 in 7 of the abnormals so failed and that the fatal accident rate was 1 in 38 normals while 1 in 6 abnormals were killed. A small sample of the tested was followed to operations where an even more suggestive result was found. Of 53 pilots who reached operational squadrons only 3 of the 41 normal reactors became casualties against 5 of the 12 anxiety prone Very recently ROXBURGH *et al.* (1956) have shown that anxiety proneness has a relationship to collapse under conditions of pressure breathing.

Work by ULETT *et al.* (1953) has indicated that the resting EEG has some correlation with anxiety proneness as evaluated by psychological and psychiatric testers. For instance, records clinically judged to be moderately abnormal occur in the non-anxious in a ratio of 1 to 3·5 in anxiety prone. If the possessor of these records could be shown to correlate with RUSSELL DAVIS' tests a very strong case for EEG rejection would be made out.

Further to this, in a recent investigation KENNARD *et al.* (1955) have brought forward evidence that the use of a frequency analyser brings out a correlation between fast rhythms in the EEG pattern and anxiety proneness. This is a most helpful article because, although technically it can be adversely criticized on both electro-physiological and psychological grounds, it leads the way to modifications which may be much more fruitful than our present all or none situation which depends so largely on individual judgement.

THE ABNORMAL EEG AND HEAD INJURY

For some years all cases of head injury in aircrew, however trivial, have been referred to the neurologist and in the course of clinical investigation an EEG has been carried out. In all cases where the record has been abnormal it has been followed until it has reached a final stage of three recordings which have been consistent. I may say that in the absence of symptoms, clinical history or abnormal neurological signs, however abnormal the record, we are continuing to fly the persons concerned and we have at least a dozen people with paroxysmal records who have flown for a period up to 5 years under observation without any symptoms being shown.

In view of the supposed relationship between accidents and anxiety proneness and of anxiety proneness and the EEG it seemed interesting to investigate any connexion between abnormal EEG's and accidents. A limited survey was carried out and the results are submitted in abbreviated form.

A total of 200 consecutive cases of closed head injury were considered (an additional 14 who developed epilepsy were rejected).

Table I

Post traumatic amnesia	*EEG abnormal*	*EEG normal*
Under 1 hr (slight)	20	75
1–12 hr (moderate)	20	49
Over 24 hr (severe)	7	29
Total	47	153

The population was only selected by employment since it is the RAF procedure that all aircrew sustaining head injuries in the United Kingdom are referred to the Central Medical Establishment for review before return to flying duties. There was no age discrepancy in the two groups. No attempt was made to take account of focal manifestation in the EEG because, as

tutional basis for many of them.

Table I shows there is no great difference in the relative proportion of normal and abnormal records, irrespective of the duration of post-traumatic amnesia. In fact, when the χ^2 test is applied to the figures the difference in the observed distribution between slight and severe cases and between slight and all other cases is not significant.

It is suggested, therefore, on these findings that in this sample of closed head injuries (from whom known post-traumatic epileptics were excluded) the fact that the duration of unconsciousness and therefore, presumably, the severity of the head injury, is not significantly related to the abnormality of the EEG, indicated that the abnormalities observed after head injury may largely be constitutional and not traumatically determined. This is in line with our experience that few closed head injuries have residual neurological signs, however long the post-traumatic amnesia.

Table I also shows that of the total accident victims 47 out of 200, or 1 in 4, had abnormal records as compared with 5 per 100 of Williams normal

Relationship of an Abnormal EEG to Episodes of Unconsciousness in Aircrew

For the present discussion a series of 123 cases of loss of consciousness in aircrew which have been personally examined has been reviewed. Excluded are cases of organic neurological disorder, including sequelae open head injuries or cases considered to be of psychoneurotic origin, and cases proven to have a consistent low g threshold. The majority of cases have been reviewed in consultation with Dr. D. J. Williams

Twenty-nine of the cases were considered to be syncopal in nature and I

altitude (3 cases at over 30,000 ft) or alcoholism and extreme radial acceleration was not recorded The impression gained was that in some

Table II

	EEG abnormal	*EEG normal*	*Total*
Epilepsy—ground	27	13	40
air	11	3	14
Total	38	16	54
Loss of consciousness—			
With convulsion	12	11	23
Without convulsion	12	5	17
Total	24	16	40
Syncope	3	26	29

Most of these cases have been reviewed by the RAF Institute of Aviation ... to investigate

it is possible to suggest that the high correlation of unexplained loss of consciousness with abnormality of the EEG, as opposed to the rarity of the abnormal EEG in syncope, supports the clinical impression that this reaction is not syncopal in type and, since the distribution of abnormality approaches that in epilepsy, supports a spontaneous central basis for the episodes.

During the war studies of a similar nature were carried out by Rook in association with Williams (1947). Under Air Ministry instructions all cases of loss of consciousness in aircrew were referred to one centre. A total of 500 consecutive cases were reviewed and it was considered that 208 were primarily emotional in origin, 134 cardio-vascular and 120 neurogenic, of whom 89 were epileptic. The immediate point of interest in this study is that of the 89 cases of epilepsy only 14 had attacks in the air, while of the 134 cardio-vascular cases only 14 had attacks in the air which were unexplained

The relevant EEG findings are not in a form which allow of comparison being made, but the small number of the cases of unexplained loss of consciousness in the air, and the failure to recognise any central features in them gives strong support to the view that under modern flying conditions we are seeing a new reaction type.

Conclusions

(I) There is some evidence that the abnormal EEG may have some connection with accident liability and with failure in military flying. There is ... an opinion either as to ... oportion

... bnormal record of the paroxysmal type at rest is so closely linked with physical or psychological breakdown that candidates with such records should not be

accepted for training. However, our follow up of experienced pilots with such abnormal records suggests that any related symptoms are likely to have been revealed before completion of training.

(III) There is accumulating evidence which should be pursued that certain factors in an EEG which is clinically within normal limits may be related to anxiety reactions of the type which interfere with efficient performance of flying duties This should be pursued in the hope that the EEG may prove an effective method of grading reaction to anxiety-provoking situations.

Sommaire

Les anomalies de l'électroencéphalogramme peuvent être constitutionnelles ou [illegible]

[illegible] *nerveux, laquelle peut s'étendre au-delà de la 20° année Les techniques d'activation, telles que le scintillement, le métrazol, doivent jusqu'à nouvel ordre être limitées aux recherches de laboratoire, car elles demandent trop de temps et de personnel spécialisé pour être utilisées en pratique courante*

Jusqu'à présent, les études de contrôle sur l'EEG anormal sont trop peu nombreuses pour avoir une valeur statistique Les anomalies constatées chez 10 *à* 20 *pour cent de la population nous renseignent sur une faible part de l'ensemble du Personnel Navigant, et il est évident que les examens cliniques et psychiatriques décèlent une grande proportion de ces anomalies Il est possible que les troubles caractériels s'accompagnant souvent d'EEG anormal ne soient pas incompatibles avec le vol. Il faut souligner toutefois l'importance de ces facteurs et spécialement de l'anxiété · il semble bien avoir un rapport entre l'EEG et la tendance à l'anxiété*

L'analyse d'une série de sujets atteints de lésions fermées de la tête montre qu'il y a une relation entre la tendance aux accidents et l'anomalie électroencéphalographique. Elle fait penser que l'importance du facteur traumatique dans les séquelles de ces lésions a été surestimée.

Enfin il y a une relation entre l'EEG anormal et les réponses physiologiques anormales à l'hyperventilation, à l'hypoxie, aux accélérations Dans les incidents inexpliqués avec perte de connaissance en l'air, on n'a pas trouvé de rapports spéciaux avec de tels facteurs, mais on a l'impression qu'ils sont d'origine cérébrale plutôt que cardio-vasculaire.

References

Buchthal, F. and Lennox, M *EEG clin Neurophysiol.* 5, 545, 1953.

Franks, W. F , Kerr, W. K. and Rose, B. *J. Physiol.* 104, 10P, 1945.

Gastaut, H Personal communication, 1955.

Kennard, M. A , Rabinowitch, B A. and Fister, W. P *EEG clin. Neurophysiol.* 9, 29, 1955.

Muller, R. *EEG clin Neurophysiol* 9, 25, 1955.

Mundy-Castle, A. C. *EEG clin. Neurophysiol.* 9, 1, 1953

Picard, P *et al* Personal communication, 1955.

REID, D D. "Influence of Psychological Disorder in Efficiency in Operational Flying". FPRC 508, 1947. Unpublished report Quoted in Air Publication 3139, Psychological Disorders in Flying Personnel of the Royal Air Force investigated during the 1939–1945 war, p. 190, HMSO.

ROOK, A. F. *Quart. J. Med.* (N.S.) **16**, 181, 1947.

ROXBURGH, H L., ERNSTING, J. and BADGER, I. J. "The Pressure Jerkin". FPRC 948, Air Ministry, 1956.

RUSSELL DAVIS, D. "Pilot Error". Air Publication 3139A. HMSO, 1948.

SCHWAMB, H. H., CLAUSEN, R. E. and SUMNER, J. W. *Arch. Neurol. Psychiat.* **75**, 198 1956.

ULETT, G. A., GLESER, G., WINOKUR, G. and LAWLER, A. *EEG clin. Neurophysiol.* **5**, 23, 1953.

WALTER, W. G. Personal communication. 1955.

WILLIAMS, D. J. *J. Neorol. Psychiat.* **4**, 257, 1941.

ELECTROENCEPHALOGRAPHIC EVALUATION OF NAVAL AVIATION CANDIDATES

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THE research department of the U.S. Naval School of Aviation Medicine at Pensacola, Florida has made another attempt to adapt electroencephalography to the selection processes currently applied to candidates for training in aviation. The initial work in this field for the Navy was accomplished by FORBES and DAVIS[1] at Pensacola in 1940–41, and it was felt that resumption of this investigation should be undertaken because of the rich dividends accruing with a satisfactory objective method for selecting out abnormal psychomotor reactors and potentials who would feasibly be riper material for aircraft accidents than individuals not so-afflicted.[2]. In addition, the possibility of determining superior flying ability, anxiety proneness, and potential "war neuroses" types by means of EEG, stirs hopeful speculation.[3, 4, 5]

Despite enthusiastic reports to the contrary[3] and in keeping with the experience of the majority of workers in this field, no technique or means of analysis of EEG's on aviation candidates has been without significant equivocation[6]

The following are among those factors which plague the careful observer who attempts to discriminate by means of electroencephalography among applicants for flying training

(*I*) *Population*

The individuals who apply for aviation training in the U.S. Navy are young healthy males between the ages of 18 and 25 years who, historically, give no personal or familial evidence of convulsive seizures, fainting spells or behaviour which can be construed to reflect potential abnormal cerebral physiology.

(*II*) *Technique of testing*

Assuming a satisfactory technical method, in order to investigate a large, everchanging population, time becomes critical A short period of time is allotted for the physical and psychological examination of subjects prior to the commencement of training. The value of a 30 min testing period in the lifetime of an individual is questionable.

(*III*) *Presence of false positive reactors*

It has been pointed out by many investigators that about 10 to 15 per cent of so-called "normals" will exhibit EEG records compatible with a diagnosis of altered cerebral physiology.

(IV) Validity of analytic methods

Among disease processes which have many methods of treatment, it usually follows that there is no single "best" method. The similar lack of accord among authorities as to diagnosis of cerebral pathology contributes to the confusion surrounding validity in EEG analysis.

(V) Evaluation of performance of tested candidates and controls

(a) Correlation of EEG results with pilot performance and abilities on a prolonged basis is fundamental to a study of this sort if the validity of this means of selection is to be demonstrated. Grading of naval aviation candidates on a psychological basis and on a performance basis during the training period has been demonstrated to be excellent. Following the training period, however, no good accepted method for evaluation is evident.

(b) Loss of subject material because of (i) selecting out of those individuals deemed potential reactors, (ii) loss due to attrition from the program for a variety of causes, and (iii) loss due to death of individuals in aircraft accidents in which altered cerebral functioning could or need not have been indicted as the etiological factor will account for further difficulty in rational analysis

(c) Lack of exposure of pilots to conditions which could feasibly "trigger-off" psychomotor aberrations serve also to confuse the over-all evaluation of this method of testing.

(VI) Artifact

Machine- and patient-induced artifact can contribute heavily to the difficulty in arriving at truthful, conclusions concerning subjects.

Procedure

The present program at this facility consists of examining 30 min electroencephalographic tracings of many or all flight candidates. Hyperventilation and photic driving are employed during the course of the examination to provoke altered wave patterns in susceptible subjects.[7, 8, 9, 10] The use of an electronic "brain wave analyzer" has been incorporated into the procedure The analyzer consists of a series of resonator-integrator units which alternately store on condenser plates and discharge to a write-out pen, the energies in each of 22 frequencies between 3 and 33 c/s The analyzer write-out is superimposed on the corresponding EEG tracing. The exhibited energy in each frequency can be read off directly from the scale of a transparent template placed over the record. The advantage of such a system can be readily envisioned.

Two additional testing means are being considered. The stipple test of von Palthe[11, 12] is being introduced into this investigation to supply additic[illegible]

ga[illegible]

an[illegible]

data.

Discussion

Statistically significant data on objective examination of military aviation training applicants by means of electroencephalography have not appeared as of this date. The efforts of the best workers in this field have yet to reveal techniques and analyses applicable to large groups of candidates, otherwise suitable for aviation training.

The primary good which has resulted from the work of EEG laboratories all over the world, lies in the selecting-out of obvious epileptiform reactors. The parameters of the broad band of marginal psychomotor reactors have not yet been clearly delineated, nor has correlation of acceptable functioning of individuals within this band been made to EEG tracings.

The method outlined above, in which electronic analysis of EEG tracings has been set forth leaves large areas for doubt concerning its efficacy. It has been mathematically computed that no mechanical analysis of spectrum frequencies is possible because of many reasons The harmonics of the dominant frequencies constitute one of the most important insolubles. It has not been shown that empirical analysis of records by such means can be correlated with training grades and other pertinent performance information. A search in this direction continues, however. A 10 year follow up and evaluation of subjects has been written into the experimental design. To paraphrase a remark by Dr. Robert Cohn of Bethesda, Maryland, "The analysis of 30,000 examples of doubt and equivocation can lead only to equivocation as a result".

In spite of the vagaries inherent in any hunt for evidence of disease by means of electroencephalography there remains a hope that a technique can be found, validated and put to use as a component part of the selection battery of tests given to flight training candidates. To this end, the research activity of this department has utilized accepted techniques and methods of [illegible]

found Enthusiasm has not attended our results The greater the progress, the less is known concerning the correlation between behaviour and the EEG of a subject.

Summary

The methods currently employed by the Research Laboratory of the U.S. School of Aviation Medicine in Pensacola, Florida to obtain, evaluate and correlate data concerning the electroencephalographic variations among candidates for flight training are depicted and commented on. At this time no means have been established to provide valid selection criteria.

Sommaire

Le laboratoire de recherches de l'École de médecine aéronautique de la Marine à Pensacola a essayé, depuis 1940, d'adapter l'électroencéphalographie à la sélection

des candidats à l'aviation. Les résultats, à l'heure actuelle, sont décevants, et cela pour plusieurs raisons:

Les candidats représentent une population jeune et saine chez laquelle les symptômes d'anomalie cérébrale sont exceptionnels. Un examen de 30 min, même avec une technique parfaite, ne représente qu'une période beaucoup trop courte de la vie d'un individu. 10 à 15 pour cent des sujets dits "normaux" donnent des tracés EEG qui pourraient être interprétés comme pathologiques. Il persiste [illegible] *se heurte à de grandes difficultés.*

L'examen consiste en un tracé de 30 min, avec stimulation lumineuse et hyperventilation, et lecture par un "analyseur électronique d'ondes cérébrales". Des épreuves complémentaires sont éventuellement effectuées avec le test de pointillage de V. WULFFTEN PALTHE, *et la Vectorencéphalographie est actuellement étudiée.*

En dehors des sujets épileptiques évidents, on n'a pas encore réussi à délimiter nettement les paramètres de la vaste bande marginale des sujets ayant une réaction susceptible d'être interprétée comme anormale. L'analyse électronique des tracés laisse persister des doutes sur sa propre efficacité.

En définitive, l'EEG n'a pas fourni, jusqu'à ce jour, de critères valables de sélection. Les recherches continuent pour trouver une méthode digne d'être intégrée dans les batteries de tests, mais plus elles progressent, moins on sait de choses sur la corrélation entre le comportement d'un sujet et son électroencéphalogramme.

The opinions or assertions contained herein are the private ones of the writer and are not official and do not reflect the views of the U.S. Navy Department or the Naval service at large

REFERENCES

1 FORBES, A. and DAVIS, H. Electroencephalography of Naval Aviators. Report No. 13. Washington, D C.: Civil Aeronautics Administration, *1943.*

2 POWELL, T. J. "Unconscious Incidents While Flying." Presented at the Aero-Medical Association meeting, Chicago, 1956.

3 THORNER, M., GIBBS, F. A. and GIBBS, E. L. "Relation Between the Electroencephalogram and Flying Ability". *War Med.* Chicago 2, 255—262, 1942.

4 ULETT, G. A. and GLESER, G. "Psychiatric Screening of Flying Personnel: The Development of Empirical Scales for the Prediction of Anxiety-proneness from the EEG and Reaction to Intermittent Photic Stimulation". Project No. 21-0202-0007. Report No. 4. Randolph Field, Texas: USAF School of Aviation Medicine, 1953.

5 HEPPENSTALL, M. E., HILL, D. and SLATER, E. "The EEG in the Prognosis of War Neurosis". *Brain 68*, 17–22, 1945.

6 Personal communications to the author.

7 GIBBS, F. A., GIBBS, E. L. and LENNOX, W. G. "Electroencephalographic Response to Overventilation and its Relation to Age". *J. Pediat.*, St. Louis 23, 497–505, 1943.

[8] BRILL, N. Q. and SEIDEMANN, H. "Electroencephalographic Changes During Hyperventilation in Epileptic and Non-epileptic Disorders". *Ann. int. Med.* 16, 451–461, 1942.

[9] GASTAUT, H. and HUNTER, J. "An Experimental Study of the Mechanism of Photic Activation in Idiopathic Epilepsy". *EEG clin. Neurophysiol.* 2, 263–287, 1950.

[10] WALTER, V. J. and WALTER, W. G. "The Central Effects of Rhythmic Sensory Stimulation". *EEG clin. Neurophysiol.* 9, 57–86, 1949.

[11] VAN WULFFTEN PALTHE, P. M. "Medical Tests for Detecting Latent Epilepsy and Fluctuations in the Level of Consciousness". *J. Aviat. Med.* 25, 275, 283, 303, 1954.

[12] VAN WULFFTEN PALTHE, P. M. *Aeromedical Acta II.* 1953, p. 35.

[13] PETSCHE, H. "The Vector EEG, a New Method to Explore Electrical Physiology of the Brain". *Wien Z. Nervenheilk.* 5, 304–320, 1952.

THE SIGNIFICANCE OF NYSTAGMUS OBSERVED IN ROUTINE OTOLOGIC EXAMINATION OF FLIGHT PERSONNEL

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Since November 1952 when I became attached to the Danish Royal Air Force as otolaryngologic adviser, I have undertaken the otologic examinations of all student pilots who presented themselves before the Medical Examination Board of the Air Force. The number of candidates examined aggregates 1338 "normal" persons

In addition to the otologic examination proper, examinations of the [illegible]

test *ad modum* Hallpike.

The examination method using Frenzel glasses is the one most frequently applied by ear clinics in Denmark where it has been systematized by S. H. Mygind.

Among the candidates examined in the course of these 3 years, 27—i e. 2 per cent of the total—were found to have spontaneous or positional nystagmus. This percentage is in accord with the percentage found by Mygind and by Knapp. These two examiners having found respectively 1 out of 81 and 7 out of 725 "normal" persons with spontaneous or positional nystagmus.

In cases where abnormal conditions were found to exist, examinations were repeated several times with intervals of a few days. If the nystagmus persisted and a reasonable cause could not be pointed out, the candidate was rejected on the assumption, also accepted by Krauss, that a constant spontaneous or positional nystagmus must always be taken to be a pathological phenomenon. In this connection I would state that we define nystagmus as the vestibular organ's physiologic reaction to a non-physiologic stimulus. That is to say that we invariably regard a case of nystagmus which repeated examinations have shown to remain unchanged as an indication of a pathological condition in the organism of the person examined.

In addition to the examinations of the student pilots I have during this period undertaken examinations every second year of all Danish military pilots. Among the latter several cases with spontaneous nystagmus and positional nystagmus were found

With regard to etiology these cases fall into the following categories:

Intoxication .	. 3
Infection .	. 5
Surmenage (stress)	. *10*

Post-traumatic	1
Labyrinthosis	1
Ménière's disease	3
Disseminated sclerosis	1
Cause unknown	2

In accordance with JONGKEES we divide vertigo and nystagmus into the following three groups

(I) vertigo and nystagmus due to disease in the vestibular organ proper,
(II) vertigo and nystagmus due to disorder in the vestibular function caused by systemic diseases,
(III) vertigo and nystagmus due to non-vestibular causes.

Regarding the three cases of intoxication, the cause was directly traceable to poisoning with cellulose varnish, tobacco and alcohol.

Out of the ten cases of stress nine were found to be due to acute over-exertion incurred by journeys, participation in social activities, etc. some few hours prior to the examination. One case was extremely obstinate, nystagmus, fatigue and slight attacks of vertigo being shown to have existed for approximately 18 months After all conceivable possibilities had been thoroughly explored, the cause was found to be that the pilot concerned had been transferred to office work (as part of his officer's training). This made him feel overworked and burdened with numerous problems which he could not manage to dispose of in time. He had worked up a dislike for his duties as a clerical officer and in this way reduced the resisting power of his entire organism His ailments vanished completely in the course of two months after he was returned to flying duty. None of the previous symptoms have reappeared This latter case must be referred to JONGKEES' third group due to non-vestibular causes.

The one case of nystagmus, shown after a cranial trauma, disappeared spontaneously in the course of about 6 weeks and must be characterized as commotio labyrinthii (S. H MYGIND) or affection of cerebral centres or pathways

Coming under the category of direct labyrinth causation (JONGKEES' group No. 2) was one case of labyrinthosis By this we mean a case with nystagmus and slight vertigo, without hearing being affected This case, like the three genuine cases of Ménière's disease found among those examined, showed intermittent symptoms, but has now over a period of more than 6 months been completely symptomless.

One of the three cases of Ménière's disease was found in a younger

been discharged, he has been completely symptomless for one year and has carried out his duties as a pilot without any inconvenience or mishap

The two other cases of Ménière's disease were both found in officers, a little advanced in years, who do not serve as pilots-in-control. The condition of both these cases is intermittent with periodic attacks of vertigo, nystagmus and reduction of hearing acuity.

In one case a positional nystagmus was shown, the cause of which could not be determined by otologic examination methods. The subsequent neurologic examination revealed indications of an organic nervous ailment in the form of disseminated sclerosis.

We have still to consider two cases of nystagmus of undetermined cause. I shall now describe these two cases in detail, as they are the reason for our request to AGARD for a discussion of the subject of *Nystagmus* in flight personnel.

In order not to make tedious repetitions, I shall only state that all the cases previously mentioned were grounded during the periods when their nystagmus was manifest. As soon as their symptoms vanished and they were found to be normal after repeated examinations, they received permission to fly.

The only pathological feature found was the sign of nystagmus which was not accompanied by any form of subjective indisposition. There was, thus, no vertigo, no nausea, no vomiting, no affection of hearing and, upon the whole, no appearance of illness of any kind whatever.

Case I: E. Ø., born on 6 October 1932.

Formerly clerical worker, now flight lieutenant.

The first time I saw him after he had completed his pilot's training was on 18 October 1954, at the Air Force otologic clinic of the Military Hospital [illegible] nystagmus [illegible] and [illegible] one position. Nor was there any spontaneous nystagmus. Caloric test, 30° C *ad modum* HALLPIKE applied to right ear showed a lateral-rotatory nystagmus from right to left lasting for 127 sec and in respect of the left ear a lateral- [illegible] The difference is so [illegible]

[illegible] examinations, inclusive of EEG, cranial roentgenogram, etc. were carried out with negative results. Only once, on 23 November 1955, the neuro- [illegible] of patella and achilles [illegible]

[illegible] as co-pilot.

Case II: H. A. P., born on 21 *May* 1931

This case was examined for the first time at the Air Force otologic clinic on 3 February 1953, after his return from U.S.A. where he had received

his pilot's training. This examination did not reveal anything abnormal in the vestibular organ. His next examination on 3 June 1955, disclosed a vertical nystagmus upwards, when he was lying on his back and, when lying on his left side, a nystagmus obliquely upwards towards right, which was the only objective symptom. There were no subjective complaints, no previous illness and nothing to account for the nystagmus discovered. The subsequent neurologic examination did not disclose anything neurologically abnormal, and EEG was normal. The Flying School reported that this pilot had always had difficulty in landing his aircraft but, apart from that, there had been no trouble with his flights.

Since then examinations have been carried out repeatedly (most recently on 5 March 1956), the result is still the same—vertical nystagmus, when lying on his back. It is still recommended that he is not to be permitted to fly as pilot-in-control. I consider a constant spontaneous nystagmus or positional nystagmus to be a pathological condition and, therefore, cannot certify the pilot examined to be fully normal from an otological point of view.

I shall now briefly give an account of a few cases that I have observed among civilian pilots.

A former military pilot, *B.P.N.* (*born on 18 February 1932*), received his pilot's training in U.S.A. where he once bailed out by parachute because of "false sensations". He was repatriated because of fear of flying. After having completed his training as a civilian pilot, he has three times made an emergency landing without any defects in the aircraft being shown. All three accidents were similar in character in that he from very low altitude made a nose landing. Numerous examinations of this pilot, carried out over a period of more than two years, disclosed a constant vertical nystagmus downwards without any other signs. He was found to be normal in neurologic respect and with regard to EEG and has, according to his own statement, never been inconvenienced by dizziness, apart from the said case of "false sensations" when he bailed out by parachute.

The second case I would mention is a student pilot, *R.H.A.* (*born on 21 June 1929*), who had passed all medical examinations before 1952, but had been rejected by the Flying School for inaptitude. He was entirely incapable of keeping bearings during instrument flying. A thorough vestibular examination disclosed a constant and unmistakable lateral nystagmus from right to left. This candidate has later become flight operator and does not any longer pilot aircraft.

The third and last case concerns a civilian pilot *V.B.A.* (*born on 16 May 1906*), who three times, without any defects in his aircraft being detectable, caused it to go into left spin without being able to recover (1932, 1952 and 1953). Repeated examinations of this pilot were made and the only sign found was a lateral nystagmus from right to left.

Our examination material thus comprises two cases of trained military pilots, one flight operator and two civilian pilots, all displaying a constant non-symptomatic nystagmus. The two military pilots have never had any difficulties in flying their aircraft, whereas, in the case of the flight operator and the two civilian pilots, a connection must be suspected between their vestibular abnormality and their difficulty in piloting aircraft.

The question is now whether or not a pilot who has been found to have a constant, unmistakable non-symptomatic nystagmus should be allowed to fly as pilot-in-control.

I shall now sum up our *conclusions:*

A constant nystagmus is, as already defined, a normal physiologic vestibular reaction to a non-physiologic stimulus, which means that a constant nystagmus is always brought about by some abnormal conditions in the body.

In the majority of cases where nystagmus has been discovered, we have been able both to point out the cause and to remove it. To a certain degree, through symptomatology, we are acquainted with the ailment. We have realized that the pilots affected had to be removed from flight service as long as their nystagmus was manifest, but that they should be permitted to fly as soon as the condition, after an adequate control period, was found to have disappeared.

In the said cases it has only been possible to detect one objective finding but no subjective symptoms so, diagnostically, we are completely at sea—an experience so often met with in the ordinary oto-neurologic clinic.

HALLPIKE maintains that a positional nystagmus must be regarded as a serious symptom, when occurring without latent periods and without *vertigo and is constantly present whenever and as long as the person examined* is lying in a certain position, and, above all, when it is not directed towards the disordered side of the body.

BÁRÁNY and CRABBE maintain that the presence of a positional nystagmus is mainly an indication of central lesions

FLETCHER states that a positional nystagmus is often the pre- or post-stage of a constant nystagmus. This is also maintained by NYLEN and SEIFERTH and is in accordance with our experiences.

MUSKENS maintains that lack of coordination between spontaneous deviations (*Romberg*, walk test, pointing test, nystagmus and vertigo) is an indication of a central disturbance.

AUBRY, HENSCHEL, ROMER, CRANMEER and several others point to the fact that lateral, spontaneous nystagmus primarily occurs owing to processes in the hind brain.

In several cases we have detected a spontaneous or a positional nystagmus as the first and only sign of intracranial disease (disseminated sclerosis or cerebral tumor). The possibility that the nystagmus detected in the five cases cited may be the initial symptom of organic nervous disease should not be ignored

On this basis our decision was to recommend these persons not to be allowed to fly as pilots-in-control

However, as our experience in this special field is extremely limited I have attempted to supplement my knowledge and experiences by talks with flight surgeons in U.S.A , the United Kingdom and the Netherlands. Thus far I have found no one familiar with the importance of this problem.

Professor JONGKEES from Amsterdam expressed the opinion that cupulometric examinations of the persons in question might perhaps prove valuable, but as we in the Danish Air Force do not have the necessary apparatus at our disposal, we have been unable to obtain such measurements and have

with avidity seized the opportunity of having the problem brought to light through AGARD.

SOMMAIRE

En trois ans, sur 1338 sujets "normaux" candidats à l'aviation, 27 présentaient un nystagmus spontané ou de position, à l'épreuve des verres de Frenzel complétée dans les cas douteux par l'épreuve calorique selon HALLPIKE.

Le nystagmus constitue une réaction physiologique de l'organe vestibulaire à un stimulus non physiologique. Quand il est permanent il correspond à un état pathologique de l'organisme et le candidat doit être refusé.

En outre, l'auteur a examiné des pilotes militaires dans leur deuxième année [illegible]

phoïde); un traumatisme crânien, un cas de labyrinthose (nystagmus avec léger vertige) sans atteinte de l'ouïe; trois maladies de Ménière; une sclérose en plaques, et dix cas de surmenage. Dans deux cas, la cause resta ignorée. L'auteur décrit ces deux cas en détail pour avoir l'opinion des confrères étrangers. Il en a également observé trois chez des pilotes civils.

D'une façon générale, tous les sujets atteints ont été interdits de vol tant que dura leur nystagmus. Après disparition de celui-ci à plusieurs examens répétés, ils re- [illegible]

Cette expérience, en somme limitée, serait utilement complétée par les observations qui auraient pu être faites à l'étranger.

The question is now whether or not a pilot who has been found to have a constant, unmistakable non-symptomatic nystagmus should be allowed to fly as pilot-in-control.

I shall now sum up our conclusions

A constant nystagmus is, as already defined, a normal physiologic vestibular reaction to a non-physiologic stimulus, which means that a constant nystagmus is always brought about by some abnormal conditions in the body.

In the majority of cases where nystagmus has been discovered, we have been able both to point out the cause and to remove it. To a certain degree, through symptomatology, we are acquainted with the ailment. We have realized that the pilots affected had to be removed from flight service as long as their nystagmus was manifest, but that they should be permitted to fly as soon as the condition, after an adequate control period, was found to have disappeared.

In the said cases it has only been possible to detect one objective finding but no subjective symptoms so, diagnostically, we are completely at sea—an experience so often met with in the ordinary oto-neurologic clinic.

HALLPIKE maintains that a positional nystagmus must be regarded as a serious symptom, when occurring without latent periods and without vertigo and is constantly present whenever and as long as the person examined is lying in a certain position, and, above all, when it is not directed towards the disordered side of the body.

BÁRÁNY and CRABBE maintain that the presence of a positional nystagmus is mainly an indication of central lesions.

FLETCHER states that a positional nystagmus is often the pre- or post-stage of a constant nystagmus. This is also maintained by NYLEN and SEIFERTH and is in accordance with our experiences.

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AUBRY, HENSCHEL, ROMER, CRANMEER and several others point to the fact that lateral, spontaneous nystagmus primarily occurs owing to processes in the hind brain.

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On this basis our decision was to recommend these persons not to be allowed to fly as pilots-in-control

However, as our experience in this special field is extremely limited I have attempted to supplement my knowledge and experiences by talks with flight surgeons in U.S.A , the United Kingdom and the Netherlands. Thus far I have found no one familiar with the importance of this problem.

with avidity seized the opportunity of having the problem brought to light through AGARD.

Sommaire

En trois ans, sur 1338 sujets "normaux" candidats à l'aviation, 27 présentaient un nystagmus spontané ou de position, à l'épreuve des verres de Frenzel complétée dans les cas douteux par l'épreuve calorique selon HALLPIKE.

Le nystagmus constitue une réaction physiologique de l'organe vestibulaire à un stimulus non physiologique. Quand il est permanent il correspond à un état pathologique de l'organisme et le candidat doit être refusé.

En outre, l'auteur a examiné des pilotes militaires dans leur deuxième année

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phoïde), un traumatisme crânien; un cas de labyrinthose (nystagmus avec léger vertige) sans atteinte de l'ouïe; trois maladies de Ménière; une sclérose en plaques, et dix cas de surmenage. Dans deux cas, la cause resta ignorée. L'auteur décrit ces deux cas en détail pour avoir l'opinion des confrères étrangers. Il en a également observé trois chez des pilotes civils.

D'une façon générale, tous les sujets atteints ont été interdits de vol tant que dura leur nystagmus. Après disparition de celui-ci à plusieurs examens répétés, ils reprirent leur activité aérienne. Mais s'il existe une raison de penser que le nystagmus constitue le symptôme initial d'une affection neurologique organique, il est recommandé de ne pas laisser voler ces sujets comme premier pilote.

Cette expérience, en somme limitée, serait utilement complétée par les observations qui auraient pu être faites à l'étranger.

The question is now whether or not a pilot who has been found to have a constant, unmistakable non-symptomatic nystagmus should be allowed to fly as pilot-in-control.

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Professor JONGKEES from Amsterdam expressed the opinion that cupulometric examinations of the persons in question might perhaps prove valuable, but as we in the Danish Air Force do not have the necessary apparatus at our disposal, we have been unable to obtain such measurements and have

with avidity seized the opportunity of having the problem brought to light through AGARD.

SOMMAIRE

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Cette expérience, en somme limitée, serait utilement complétée par les observations qui auraient pu être faites à l'étranger.

THE SIGNIFICANCE OF NYSTAGMUS IN AVIATION MEDICINE

Ashton Graybiel

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The significance of nystagmus in aviation medicine centers around its use as a physical sign and the fact that it may influence visual perception In this report we will consider, first, the importance of nystagmus as a sign of disease or disorder, second, the value of nystagmus tests as indicators of aptitude or fitness for flying and, third, the importance of nystagmus in visual perception during flight. It should be emphasized that the remarks [illegible] subject matter.[1,2,3,4,5]

Clinical Aspects

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From a practical point of view the problem is two-fold. One aspect concerns the observations which might be made at the time the flyer is inducted into the service and at the time of his subsequent periodic physical examinations. The second aspect is concerned with how much the flight surgeon should be expected to know about nystagmus in connection with the medical care of flying personnel.

The initial examination either in the case of the prospective flight student or pilot is valuable not only in disclosing defects which are disqualifying but also in providing baseline data for purposes of future comparison. In other words, this examination should include every item which is likely to come up in the future. The possibilities with regard to nystagmus fall into three categories. First, spontaneous nystagmus; this would not require special apparatus and the interpretation is usually clear-cut, at least as to whether or not spontaneous nystagmus has pathological significance. Second, positional nystagmus[6,7]; this requires not only a knowledge of the procedure but also requires considerable clinical experience in evaluating the findings, although a positive test may be regarded as having pathological significance. Third, induced nystagmus; here we must consider the type of test or tests to carry out, the quantitive measurements to be made, and the experiences needed for proper evaluation. Relatively simple tests would include the determination of the thresholds of sensitivity, the Bàràny chair

or Kobrak minimal irrigation test.[5] More extensive tests including cupulometry[8] could hardly be justified from the purely clinical viewpoint.

Historically, it is worth noting that interest in nystagmus, at first high,[9, 10] has fallen to the point where the word does not appear on the aviation medical examination form now used by the U S. Navy and Air Force. [illegible] in the direction where disorders of the labyrinth have assumed new or greater importance?

In the light of past experience and with due regard to the changing aspects of aviation medicine including the keen competition for the time and interest of the flight surgeon, it is my opinion that the only item to include in the original medical examination is the observation if spontaneous nystagmus is present. There is room here for the discussion of viewpoints different than my own.

The periodic or yearly examination of flight personnel should not include additional items with regard to nystagmus tests. This opinion would hold unless it could be shown that ageing tended to increase, to an important degree, the likelihood of disease or disorder which tests of nystagmus might disclose.

The other question still remaining is whether flight surgeons should be taught special tests for nystagmus in the hope that these would prove useful in the care of the flyer. In answering this question I am indebted to Dr. Joseph B. Dominey who has had extensive experience, as a specialist in otolaryngology, in caring for U.S. naval aviators. His opinion is that vestibular disease is encountered so rarely in pilots that he would not recommend that flight surgeons be taught the special nystagmus tests. In this opinion I fully concur.

In summarizing this section on the clinical aspects of nystagmus, we conclude that a look for spontaneous nystagmus is the only item required and that the teaching or the carrying out of special tests of nystagmus is not justified except on an exploratory or research basis

Nystagmus Tests and Flight Aptitude

Nystagmus is induced readily in healthy persons and there are important individual differences in response. We must consider now the importance of such testing in aviation medicine This will be discussed briefly under two headings, namely, optokinetic or ocular nystagmus and vestibular nystagmus.

Optokinetic nystagmus

Two types of optokinetic nystagmus have been described, active and passive.[5, 11] The former is called forth when a person fixates a moving object in an otherwise stationary visual field. The passive form does not require fixation because all objects in the visual field move. These forms of nystagmus

depend on a reflex center in the visual cortex but the active form may be influenced by corrections for error probably arising elsewhere. Although these forms of nystagmus have received considerable attention, they have not been exploited fully in aviation medicine. LUDVIGH and his associates working at the U.S. Naval School of Aviation Medicine have been carrying out routine tests of dynamic vision on students entering flight training.[12] Although these investigators are interested in recording compensatory eye movements, on the basis of these tests the best indicator seems to be in the ability of the subject to identify a revolving target. The results indicate that a group of healthy young men with 20/20 vision or better show considerable individual variation in score when tested with a moving target [13] The test is reliable and is now being validated. Looking ahead to the visual requirements of the pilot in the future, we find that tests of compensatory eye movements hold increasingly greater promise.

Vestibular nystagmus

The semicircular canals and otolith organs are still regarded as a single apparatus not only by some practising physicians but also by those engaged in research studies in this field. However, a better working concept is that the non-acoustic portion of the labyrinth consists of two functionally independent organs. The otolith organs respond to the force of gravity and tend to orient us in the direction of the lines of force. They respond to rectilinear accelerations inasmuch as these are equivalent to gravitational force, but stimulation of this organ does not give rise to nystagmus, hence is outside the subject matter of this report.

The semicircular canals respond to angular acceleration which gives rise to sensations of rotation and certain reflex effects, including nystagmus of the eyes.[14, 15, 16] Although angular acceleration is the physiological stimulus, the receptors in the canals may also be stimulated by other means, notably syringing with warm or cold water. Galvanic stimulation produces nystagmus; but the cupula is not displaced, and direct stimulation of the vestibular

others indirect. In a few medical centers rather elaborate procedures have been employed, two of which will be described briefly.

Investigators of the Utrech School[8, 16] have devised a rotating room in which the subject is exposed to "*small regulable stimuli*". Acceleration occurs slowly till the desired velocity is reached, then rotation is suddenly stopped; the duration of after-nystagmus is timed by means of a stopwatch. The response to graded stimuli is plotted, and the resulting curve is called a cupulogram. Experience has defined normal patterns and ranges. In practice, however, it has been found that the sensation cupulograms, i.e. duration of after-sensations of rotation, are more significant than nystagmus

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cupulogram.

There is no doubt but that nystagmus tests have added to our knowledge of the physiology of the semicircular canals and to the role they play in the human economy. Also, there is no doubt but that these tests reveal differences among healthy persons and that there is some relationship between test scores and susceptibility to motion sickness. The Dutch investigators use the nystagmus test as one of a test battery which has good validity in their experience.[20] In our small experience using the oculogyral illusion cupulogram in studying aviators complaining of motion sickness, the curves indicate that some have average and others high "sensitivity".[16, 21] This may prove to be significant in evaluating the relative importance of the semicircular canals as an etiological factor in individual cases.

In summarizing this section, it is my opinion that nystagmus tests are of great value in the elucidation of the psychophysiology of the semicircular canals and their importance in aviation medicine. Nystagmus tests are valuable in determining susceptibility to motion sickness but the validity is too low to warrant their use as a selection device. Further experience may enhance their value particularly as one test in a battery.

Nystagmus and Visual Perception

Although the discussion in this section will be concerned with vestibular nystagmus, it is necessary to mention ocular nystagmus and point out how it may be related to vestibular nystagmus. As pointed out earlier, ocular nystagmus is a compensatory eye movement originating in motion of the retinal image. It is an effect of visual perception, the while affecting it.

are usually referred to under other names.

van Dishoeck *et al.*[19] have called into question the assumption that

oculogyral illusion is a perceptual resultant of angular acceleration which is at least associated with nystagmus

* Visual factors, however, may influence rotation nystagmus

diagram in *Fig.* 1. This depicts the ampullated end of a *semicircular canal* with crista and cupula. The cupula forms a water-tight partition and when subjected to angular acceleration, it behaves as a critically damped torsion pendulum. When the ampulla is accelerated in a clockwise direction, the *inertia of the endolymph* causes it to flow counterclockwise. This displaces the cupula from its neutral position (N) toward the left (L), and so long as it is displaced a signal is generated. If clockwise acceleration is followed quickly by one of opposite sign, the two tend to cancel out and the cupula is restored quickly to its neutral position. This is the situation if a person turns the head; accelerations of opposite sign are associated with the onset and cessation of the single movement. The signal [illegible] extinguished on completion [illegible] sign follow each other ver[illegible] with displacement of the cupula to the left is not followed by an acceleration of opposite sign, the cupula returns to its neutral position very slowly by

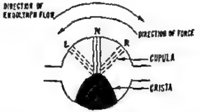

Fig. 1. Diagram of cross section of Ampulla.

virtue of its elasticity, and the signal is of long duration. This situation is encountered if a person is rotated passively at constant speed. The acceleration accompanying the onset of rotation disappears when constant velocity is reached. However, the effects of this acceleration mediated by the cupula will persist into the period of constant rotation until the cupula assumes its neutral position. In this situation, rotation at constant velocity and the cupula in its resting position, a person cannot escape a prolonged cupular signal on stopping. The accompanying deceleration displaces the cupula, and it is not followed by an acceleration of opposite sign. Hence the cupula is slow to return to its resting position.

Reference may be made to various reports describing the oculogyral illusion both [illegible] cra[illegible]

I[illegible] only in the horizontal plane. A boom attached to the trainer supports a box with perforated edges and lighted from within. A biting board is supported by an iron stanchion, and the entire apparatus is housed in a room which can be darkened.

If a subject, who has lost the function of his semicircular canals, fixates the target while the experimenter moves the Link trainer backward and forward through an arc of only forty degrees, he reports that the target does not move. However, a healthy subject under the same conditions

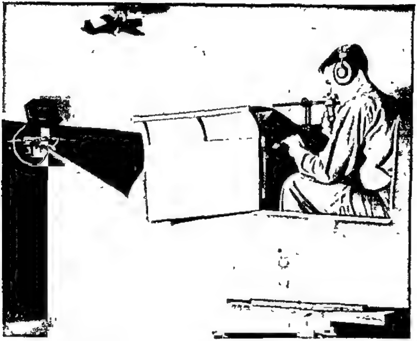

Fig 2 Link trainer modified to rotate only in horizontal plane

[facing page 300

reports that the target moves backward and forward. We have not attempted to measure the latent period between the onset of real movement and the subject's perception of movement, but the two occur almost simultaneously, as can be judged by feeling the jerk and perceiving the movement. Inasmuch as there is no relative motion between subject and target, the patient with canals destroyed sees no movement, while the healthy subject perceives an apparent movement. However, this apparent movement coincides so well with reality that the unsophisticated subject does not realize it is an illusion. Anyone may observe this same phenomenon while seated in a plane which

Returning again to the laboratory, we can demonstrate readily that the patient with canals destroyed does not perceive any movement of the target even though rotated at high velocities. However, the healthy subject, if rotated at a velocity of 25 rev/min for 3 min, perceives striking illusions of

within a period of 3 sec. On stopping, deceleration may take place in 2 sec but the apparent movement persists for 30 sec or longer.

This "unnatural" sequence of angular acceleration, constant rotation and angular deceleration is encountered in greater or lesser degrees in flight maneuvers. Inside the cabin an observer would experience the same sequence of apparent movements as the observer does in the Link trainer. The illusions are usually less striking because the accelerations are smaller and the visual field more complex. If the flyer is subjected to this pattern of angular accelerations while viewing objects outside the plane, he may observe apparent movement of these objects, especially at night.

It is necessary to mention the possibility that vestibular nystagmus during flight may be due to factors other than angular accelerations. We have examined the possibility that linear accelerations may stimulate the semicircular canals, but it appears that linear accelerations of small magnitude do not [24] It is conceivable that large G forces might cause nystagmus, but here the presence of nystagmus would be an unimportant part of the total response. Hyperventilation has been observed to cause nystagmus, and thus

stresses in causing nystagmus.

Summary

The significance of nystagmus in aviation medicine has been discussed briefly from three viewpoints, namely, the clinical aspects, the use of nystagmus as a test of fitness or aptitude for flying, and the effect of nystagmus on visual perception during flight. It was concluded that the employment of

nystagmus tests is of great importance in the hands of medical specialists but that the low incidence of labyrinthine disease in pilots does not justify at this time their regular use in the aviation examining room. Nystagmus tests disclose important individual differences among healthy persons but are of limited value in the selection of flyers. However, they are of great importance in elucidating the role of the semicircular canals not only in aviation but also in the total human economy. Nystagmus influences visual perception during flight but more investigation is needed to determine its full significance. Some of these influences are beneficial while others are illusory and hence potentially harmful.

Sommaire

La signification du nystagmus en médecine aéronautique est esposée brièvement sous trois points de vue:

—ses aspects cliniques,

—l'emploi du nystagmus provoqué comme test d'aptitude à l'aviation,

—et les effets du nystagmus sur la perception visuelle au cours du vol.

(I) Cliniquement, seule la constatation d'un nystagmus spontané présente quelque intérêt et doit être signalée dans le protocole d'examen. Il n'y a pas lieu d'introduire des tests spéciaux dans les examens de routine. Etant donnée la rareté des affections labyrinthiques chez l'aviateur, les épreuves spéciales doivent être laissées aux spécialistes.

(II) En tant que tests d'aptitude au vol, les épreuves nystagmiques montrent des différences individuelles importantes chez les sujets sains. Le nystagmus optocinétique, en tant que test des mouvements oculaires compensateurs, aura son intérêt dans l'avenir. Le nystagmus vestibulaire renseigne exactement sur la psychophysiologie des canaux semi-circulaires et la sensibilité au mal de l'air. Mais les tests n'ont pas le degré de validité nécessaire pour être adoptés comme moyen de sélection.

(III) Le nystagmus influe sur la perception visuelle au cours du vol, mais des recherches sont encore nécessaires pour en déterminer l'entière signification. Certaines de ces influences sont bénéfiques, tandis que d'autres sont génératrices d'illusions, donc éventuellement dangereuses.

References

[1] Camis, M., *The Physiology of the Vestibular Apparatus* (translated by R. S. Creed). Oxford University Press, London, 1930.

[2] Brunner, H. "Labyrinth in Aviation", *J. Aviat. Med.* 14, 132–150, 1943

[3] Frenzel, H., "Funktionen des Vestibular-apparats in ihrer Bedeutung für das Fliegen". ("Functions of the Vestibular Apparatus in their Significance for Aviation".) *Luftfahrtmed. Abh.* 1, 86–108, 1936.

[4] Krijger, M. W. W., *De Betekenis Van het Evenwichtsorgaan Voor de Vlieger.* ("The Significance of the Labyrinth in Aviation".), Drukkerij Fa Schotanus & Jens, Utrecht, 1954.

[5] Spiegel, E. A. and Sommer, I., *Neurology of the Eye, Ear, Nose and Throat,* Grune & Stratton, New York, 1944.

[6] NYLEN, C O., "Positional Nystagmus, A Review and Future Prospects". *J. Laryng*, **64**, 295–318, 1950

[7] VON DEVIVERE, D. and DE KLEYN, A., "A New Form of Position Nystagmus", *Acta otolaryng., Stockh.* 30, 97–103, 1942.

[8] VAN EGMOND, A. A. J., GROEN, J. J., HULK, J. and JONGKEES, L. B W., "The Turning Test with Small Regulable Stimuli. VI Deviations in the Cupulogram. Preliminary Note on the Pathology of Cupulometry", *J. Laryng.* **63**, 306—310, 1949

[9] JONES, I. H., *Equilibrium and Vertigo, J B. Lippincott Company, Philadelphia and London*, 1918.

[10] VAN WULFFTEN PALTHE, P. M., "Function of the Deeper Sensibility and of the Vestibular organs in Flying" *Acta otolaryng., Stockh.* **4**, 415–449, 1922.

[11] RUCKER, C. W , "Nystagmus". *Trans. Pacific Coast oto-ophthal. Soc.* **33**, 29–43, 1953.

[12] LUDVIGH, E. and MILLER, J. W., "A Study of Dynamic Visual Acuity", Joint Project NM 001 075 01, Report No. 1, Pensacola, Florida, U.S Naval School of Aviation Medicine and Kresge Eye Institute, 1953.

[13] LUDVIGH, E. and MILLER, J. W., "An Analysis of Dynamic Visual Acuity in a Population of 200 Naval Aviation Cadets", Joint Project NM 001 075.01 Report No. 7, Pensacola, Florida, U S. Naval School of Aviation Medicine and Kresge Eye Institute, 1954

[14] EWALD, J R., *Physiologische Untersuchungen uber das Endorgan des Nervus octavus*, ("Physiological Investigations of the Sense Organ of the Eighth Nerve"). J. F. Bergmann, Wiesbaden, 1892.

[15] STEINHAUSEN, W., "Ueber Sichtbarmachung und Funktionsprufung der Cupula terminalis in den Bogengangsampullen des Labyrinthes". ("Opening to view of and Testing the Function of the Cupula terminalis. on the Ampullae of the Semicircular Canals of the Labyrinth".) *Arch ges. Physiol.* **217**, 747–755, 1927.

[16] VAN EGMOND, A. A. J , GROEN, J J and JONGKEES, L. B W., *The Function of the Vestibular Organ*, S. Karger, Basel, New York, 1952.

[17] GRAYBIEL, A. and HUPP, D I , "The Oculogyral Illusion", *J. Aviat. Med* **17**, 3–27, 1946.

[18] GR[illegible] "Role [illegible] Target [illegible]

[19] VA[illegible] o-gyral Illusion and its Relation to the Nystagmus of the Eyes", *Acta otolaryng., Stockh.* **44**, 5–6, 1954

[20] VAN EGMOND, A. A J , GROEN, J. J. and DE WIT, G., "The Selection of Motion Sickness-susceptible Individuals", *Int. Rec. Med* **167**, 651–660, 1954

[21] DE WIT, G , "Seasickness (Motion Sickness)", *Acta otolaryng., Stockh., Suppl* **108**, 1–56, 1953.

[22] CLARK, B , GRAYBIEL, A. and MACCORQUODALE, K., "The Illusory Perception of Movement Caused by Angular Acceleration and by Centrifugal Force during Flight. II. Visually Perceived Motion and

Displacement of a Fixed Target During Turns", *J. exper. Psychol.* **38**, 298–309, 1948.

[23] CLARK, B. and GRAYBIEL, A., "Il disorientumento: Una della cause di errore del pilota". ("Disorientation: A cause of pilot error".) *Riv. Med. aero.* **18**, 219–641, 1955.

[24] NIVEN, J. I. and GRAYBIEL, A., "The Effect of Linear Acceleration on the Oculogyral illusion", to be published.

[25] ALEXANDER, G. and BRAUN, L., "Ueber Neurotischen Labyrinthschwindel". ("Neurotic Labyrinthine Vertigo".) *Mschr. Ohrenheilk.* **52**, 161–175, 1918.

[26] GELLHORN, E. and SPIESMAN, I., "The Influence of Hyperpnea and of Variations of the O_2– and CO_2–tension in the Inspired Air upon Nystagmus", *Amer. J. Physiol.* **112**, 662–668, 1935.

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